Bond Mutual Funds: Systemic Liquidity and Derivative Use *

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Abstract

We show, both theoretically and empirically, that there is a systemic component to liquidity management by bond mutual funds. Through cash holdings and bond prices, funds are interconnected: a fund's optimal portfolio choice depends not only on the fund's own cash holdings but also on all the other funds' cash holdings, because an aggregate cash shortfall during outflows induces downward price pressure on bonds which the fund may need to sell. This is especially important during crisis periods for bond mutual funds, who exhibit a pecking order from liquidating cash to less liquid corporate bonds when financing fund outflows. We use novel data on derivative holdings to document large cross-sectional variation in how bond mutual funds use them, and its implications on liquidity management: some hedging their returns, some amplifying them, some not using them at all.

Keywords: Systemic liquidity management, Derivatives, Cash holdings, Pecking order, Hedging

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1 Introduction

Since the global financial crisis, liquidity management and financial stability of open-end bond mutual funds have been at the centre of discussions among policy makers and asset managers. Although financial stability is fundamentally rooted on how funds' liquidity is connected to each other in the economy, common practice in liquidity management in mutual funds is to think of a fund in isolation and focus on the holdings within a fund to aggregate up to a fund-level liquidity measure: whether it is the size-weighted average of liquidity, cash holdings relative to assets under management, or other fund characteristics. This paper aims to shift attention to a set-up where mutual funds are interconnected through asset prices and portfolio choices.

We show, both theoretically and empirically, that there is a systemic component to liquidity management by bond mutual funds. That is, a fund's optimal portfolio choice depends not only on the fund's own cash holdings, but also on all the other funds' cash holdings. This is because an aggregate cash shortfall, i.e., outflows not covered by cash reserves and inflows, induces downward price pressure on bonds which the fund may need to sell. Funds are directly connected to each other by sharing asset prices, which are affected by choices of cash holdings by other funds in the economy. This is especially important during crisis periods for bond mutual funds, who exhibit a pecking order from liquidating cash to less liquid corporate bonds when financing fund outflows.

Empirical evidence in the literature also points to the importance of systemic liquidity risk. The timing of mutual fund flows is typically positively correlated across the cross-section of funds, particularly during market downturns (Kim (2021)). As a result, mutual funds often want to trade the same securities, and in the same direction, as other funds, particularly when funds experience outflows (Goldstein, Jiang, and Ng (2017), Cai, Han, Li, and Li (2019), and Falato, Goldstein, and Hortascu (2021)). So the illiquidity spillover from aggregate trading represents a negative externality imposed on funds' secondary market trading, and this contributes to systemic liquidity risk in the corporate bond market, with liquidity costs exacerbated at the most inopportune times and in the most inopportune bonds, as prices are driven lower by price pressure, in an over-the-counter (OTC) dealer market where there typically isn't much depth without a price concession.[1] So to mitigate the high cost of trading regularly and in large size, funds use their cash reserves (Chernenko and Sunderam (2020) and Pastor, Stambaugh, and Taylor (2020)), and more recently derivatives, to manage the liquidity risk of investor redemptions from their portfolios. As a result, funds face trading costs and bond returns which depend not just on their own cash holdings, derivative holdings, trading, and fund flows but also on other funds' holdings, trading, and fund flows too.

We first model the theoretical trade-offs that funds face when they use cash to invest in risky assets, like corporate bonds. The benefit is a higher expected return from the risky asset over safe cash. But the costs are several: an increase in the market risk of their portfolio, whose cost is magnified by funds' risk aversion or value-at-risk constraints; an increase in the chance of a cash shortfall if their future fund outflows exceed their inflows and cash reserves; and, in the event of a cash shortfall, an increase in liquidity costs from liquidating bonds, which they sell at a larger haircut than cash. The magnitude of the haircut they face if they need to sell bonds is modeled as proportional to the total quantity of selling of that bond by all funds, representing temporary price pressure. So liquidity costs are particularly large when funds' trading is positively correlated and large, for instance due to correlated fund flows, if a fund is trading in the same direction as the herd. The functional form for the price and haircut can be motivated for instance by Randall (2021b) who shows theoretically that the deviation of an asset price from fundamental value in an OTC dealer market is proportional to the endogenously negotiated trade size, where the coefficient of proportionality is a function of dealer:customer relative bargaining power, bond risk, dealers' inventory costs or effective risk aversion, and the expected time to find another counterparty.

Solving our model, and using market clearing, gives expressions for funds' optimal trading, expected bond return, expected liquidity haircut, and the liquidity-value-at-risk.[2] The liquidity

[1] Even in times where prices aren't falling, liquidity for most bonds is relatively weak compared to equities (Bao, Pan, and Wang (2011), Dick-Nielsen, Feldhütter, and Lando (2012), and Randall (2021a)).

[2] Liquidity-value-at-risk is computed as the probability of a cash shortfall multiplied by the liquidity cost of selling illiquid bonds due to that shortfall.

haircut is endogenously determined through the aggregate equilibrium trading of all funds which sets the asset's price. The model highlights how funds' cash holding, optimal trading, and assets' expected returns and liquidity costs are determined not just by funds' individual portfolio holdings and fund flows, but also by the aggregate portfolio holdings and fund flows of other funds. In the baseline case where a bond price does not deviate from the fundamental value, optimal bond trading depends just on the bond's expected return and risk. However, once we allow bond price to temporarily deviate from the fundamental value as a function of the aggregate trading, other funds cash shortfall affects optimal bond trading through liquidity haircut. This emphasizes and motivates the systemic component to liquidity risk, which we test and verify using corporate bond mutual fund data.

Empirically, we find that bond mutual funds sell corporate bonds less sensitively during outflows when they hold a larger share of assets in cash. They tend to sell bonds more sensitively during outflows when other funds are experiencing cash shortfall, i.e. large outflows relative to cash reserves. This effect of cash holdings on bond trading is muted during periods of inflows and in the case of government bond trading.

Bond mutual funds exhibit a strong pecking order of what they choose to sell in response to fund outflows. When outflows are small relative to cash reserves, they use cash rather than selling corporate bonds. However, when outflows are large relative to their cash reserves, they turn to corporate bonds and use less cash to service outflows. Sensitivity of cash (bond) trading during outflows monotonically decreases (increases) in cash shortfall. Compared to a counterfactual case where mutual funds sell all their assets proportionately to outflows, pecking order in bond funds could lead to a sudden large selling in the illiquid corporate bond market when outflows exceed the cash reserves in many funds at the same time, highlighting the importance of considering cash holdings of other funds in the economy.

Bond mutual funds hold more than just cash and bonds. In particular, they also hold derivatives and file their positions with the SEC. We collected this derivative holding data in the months pre-

Covid, at the start of the Covid outbreak, and in the recovery phase, seeing interesting dynamics over that tumultuous time. About half the funds in our sample hold at least one derivative at one point in time at least. Of those, some use them to hedge their returns and some to amplify them. On average hedging funds hold less cash, more corporate bonds, and larger derivative positions than amplifying funds.[3] Overall, though, hedging funds have lower systematic bond market risk than amplifying funds based on total fund return. This reflects the dominating effect of derivative holdings in fund returns, and therefore its impact on fund flows. Net fund inflows tend to be higher for amplifying funds, but also more volatile, than for hedging funds.

Derivative use is associated with differential portfolio choice in liquidity management across funds. Amplifying and hedging funds' trading of corporate bonds is sensitive to the interaction of fund flows with cash holdings. Hedging funds typically attract investor flows while amplifying funds have outflows on average. But both hedging and amplifying funds have a cash position which is negative on average, and hold insufficient cash to meet investor redemptions. But the trading of no-derivative funds, who typically hold enough cash to meet their redemptions, is not significantly sensitive to that interaction.

We estimate the cash shortfall probability in the pre-Covid and recovery phases, seeing substantial variation both in the cross-section between funds, and in the time-series before and after the outbreak of Covid-19. Hedging funds tend to have lower cash reserves, so higher cash shortfall probability than amplifying funds during all time periods. Following the outbreak, both hedging and amplifying funds experience lower cash holdings, which increased the cash shortfall probability during the recovery phases.

Asset pricing tests using liquidity costs, changes in liquidity costs,[4] and corporate bond returns all highlight that mutual funds' aggregate trading are empirically relevant for asset prices in the

[3]We rank funds by the time-series correlation between derivative returns and fund returns in the pre-Covid period, and classify funds as either 'hedging' (the lowest / most negative correlation tercile) or 'amplifying' (the highest correlation tercile).

[4]Figure 5 shows that liquidity costs, and the change in liquidity costs, spiked in the GFC and Covid-19 periods. The level was higher in the GFC, but the change was higher at the outbreak of Covid-19.

bond space. In the tests, we also add aggregate cash shortfall as a 'primitive' variable of the aggregate trading. This is to run horse-race tests to see if mutual funds' aggregate trading and aggregate cash shortfall have independent explanatory power on asset prices and, if so, during which period. We find that, when funds are on aggregate selling a corporate bond, its liquidity costs (and changes in liquidity costs) increase and its returns decrease. The effect of funds' trading on liquidity costs are an order of magnitude larger at the Covid-19 onset in March 2020, and even stronger in the Financial Crisis in September 2008. Importantly, funds' aggregate cash shortfall also becomes statistically significant in explaining all of liquidity costs, changes in liquidity costs, and corporate bond returns during Covid-19, after controlling for the aggregate trading as well as security-level trading dollar volume (both contemporaneous and lagged), interest rate risk, credit risk, and size. The significance of aggregate trading and aggregate cash shortfall highlights the systemic importance of bond mutual funds in the corporate bond market, with funds needing to account for the holdings and trading of their peers due to their connections through asset prices, in particular during the recent Covid-19 crisis.

Relation to existing literature

Our paper intersects several strands of growing literature, which we aim to merge in this paper: liquidity management, systemic risk, price pressure of flows, and derivative use by mutual funds.

With daily investor redemptions being the fundamental characteristic of any open-end mutual funds, cash holdings and liquidity management have been studied in the literature. Connor and Leland (1995)'s theoretical model shows that funds maintain a cash position in a min-max range, only actively changing it when in-/out-flows are extreme, trading off expected return and tracking error with transaction costs. Morris, Shim, and Shin (2017) show theoretically, if asset managers use cash holdings as a buffer to meet redemptions, they can mitigate fire sales of their assets. If they hoard cash in response to redemptions, they will amplify fire sales. Empirically, cash hoarding is found to be the rule rather than the exception, and less liquid bond funds display stronger cash hoarding. Chernenko and Sunderam (2020) find that mutual funds hold cash to accommodate flows, but don't fully mitigate price impact. Pastor, Stambaugh, and Taylor (2020) find that funds with larger size, lower expense ratios, and higher turnover hold more liquid portfolios. Ma, Xiao, and Zeng (2020) find that in meeting redemptions during the Covid-19 crisis, bond mutual funds first sold their more liquid assets, generating the most selling pressure in more liquid asset markets. Investors' flight to liquidity was thereby turned into an aggregate reverse flight to liquidity. The Federal Reserve's program of buying illiquid bonds alleviated fund outflows. Schrimpf, Shim, and Shin (2020) find that mutual funds holding illiquid assets in March 2020 added to their cash buffers even after meeting investor redemptions. Jiang, Li, and Wang (2021) show that during tranquil market conditions, corporate bond mutual funds reduce liquid asset holdings to meet redemptions, temporarily increasing relative exposures to illiquid asset classes. When aggregate uncertainty rises, they scale down their liquid and illiquid assets proportionally to preserve portfolio liquidity. Fund redemptions lead to more corporate bond selling during high-uncertainty periods, which generates price pressures and predicts strong return reversals. Simutin (2020) finds that actively managed equity funds with high excess cash outperform their low excess cash peers, by making superior stock selection decisions, and satisfying fund outflows and controlling transaction costs.

Although not mutual exclusive, a group of papers focus on systemic risk and financial stability implications from spillover effects of investor redemptions. Zeng (2020) models the dynamics of mutual fund runs, motivated by a first-mover advantage in redemptions. Goldstein, Jiang, and Ng (2017) find that bond fund outflows are more sensitive to bad performance than their inflows are sensitive to good performance, particularly when they have more illiquid assets and when market illiquidity is high. Cai, Han, Li, and Li (2019) find evidence of institutional herding in the corporate bond market, particularly when selling, for speculative-grade, small, and illiquid bonds, and during the financial crisis. Falato, Goldstein, and Hortascu (2021) find that fire-sales which are induced by redemptions have spillover effects among funds with the same assets. Choi, Hoseinzade, Shin, and Tehranian (2020) find little evidence that bond fund redemptions drive fire sale price pressure.

They attribute their findings, which contrast with those found for equity funds, to funds' liquidity management strategies.

There is relatively little literature on derivative use by mutual funds. Two recent working papers are Kaniel and Wang (2021), who examine derivative use and fund performance by equity mutual funds, and Sialm and Zhu (2021), who examine foreign currency derivative use in international fixed income mutual funds.

Section 2 describes the model and predictions. Section 3 describes the data. Section 4 describes the empirical analysis. Section 5 concludes. Proofs related to the model are in the Appendix.

2 Model

We solve a model of mutual fund trading to help develop our intuition around the trade-offs faced by mutual funds when trading bonds, and to show how bonds' endogenous liquidity costs and expected returns have systematic components driven by other funds trading, which in turn is driven by their holdings.

2.1 Set-up

There are a large number of funds, who each hold a portfolio of cash and a single bond. Their cash holding in dollars, and the number of units of the bond, leaving time t are denoted $cash_t$ and $bonds_t$, respectively. The cash is safe and completely liquid but earns zero interest, while the bond's price p_t is risky and possibly illiquid but has a positive expected return. We can think of both the return and the liquidity of the cash and the bond not just in an absolute sense, but also a relative sense, still with cash having a lower interest rate than the expected return of the risky bond, and being more liquid if not perfectly liquid. So cash here could be interpreted as a Treasury bond, for example.

There are 2 rounds of bond trading. At the start of each round funds receive random investor fund net outflows f_t or net inflows $-f_t$. The inflows arrive in the form of cash, and the outflows have to be funded by cash. The fund buys q_t units of the bond at time t, or sell $-q_t$ units. So $cash_t$ and $bonds_t$ evolve as described in the timeline.

Figure 1: **Timeline.** This figure shows the timeline of how a fund's cash and bond holding evolve over 2 rounds of trading

$cash_{t-1}$ | $cash_{t-1} - f_t - p_t q_t = cash_t$ | $cash_t - f_{t+1} - p_{t+1} q_{t+1} = cash_{t+1}$

$t-1$ | t | $t+1$

$bonds_{t-1}$ | $bonds_{t-1} + q_t = bonds_t$ | $bonds_t + q_{t+1} = bonds_{t+1}$

$t-1$ | t | $t+1$

In the final round of trading, if funds have insufficient cash to meet any net fund outflows then they sell just enough bonds to meet them, otherwise they do not trade. Implicitly we are assuming a pecking order here, with funds selling their most liquid assets first (cash) before selling their next most liquid assets (bonds). Since individual funds are either selling or not trading in the final period, the total net trading of all funds is negative, and the selling pressure drives the transaction price at which the funds sell to their dealers below the bond's fundamental value. So bonds who are selling funds suffer a haircut, represented by the difference between the fundamental value and the price at which they sell.

In the first round of trading, funds face a number of trade-offs when deciding how many bonds to buy or sell. Buying more bonds will increase the expected return of their portfolio, but also increase their portfolio risk, and increase both the chance that they will have a cash shortfall to meet their net redemptions and the total slippage they would incur by having to sell more bonds if they had a shortfall at a price below the bond's fundamental value.

2.2 Bond transaction price

The price for all funds at time t is specified as

$$p_t = v_t + c_t Q_t \tag{1}$$

where v_t is the fundamental value of the bond, $c_t > 0$ is a bond-specific liquidity cost, and multiplied by Q_t, the net number of units of the bond which are bought by funds at time t. So if funds are overall net buyers, the price is above fundamental value, and if funds are overall net sellers, the price is below fundamental value. Each fund is assumed to be so small that their individual trading q_t does not affect total trading Q_t. If a fund is trading in the same direction as the market, i.e. $sign(q_t) = sign(Q_t)$, they will effectively pay a transaction cost $c_t Q_t$ per unit traded, whether buying or selling. If they are trading in the opposite direction to the market they receive that transaction cost per unit traded. The specification of this price can be motivated by e.g. Kyle (1985) or Randall (2021b), who shows that the price for an individual customer trading with a dealer in an OTC market is $p_t = v_t + c_t q_t$ where both price and quantity are both endogenous, negotiated by Nash bargaining between customer and dealer. c_t is shown to be a function of their relatively bargaining power, the bond's trade frequency, its price risk, and the dealer's time-varying cost of holding inventory. In this paper we are effectively assuming that there is one price determined by aggregate trading of all funds. c_t could still be determined by the bond's trade frequency, and the dealer's time-varying cost of holding inventory, but not by individual customer bargaining power, but loosely some aggregate bargaining power of the funds who are trading at that point in time. The liquidity cost, i.e. the deviation of the price from fundamental value, $c_t Q_t$, is endogenously determined by aggregating individual trading into Q_t.

2.3 Timeline

Each fund follows the following time-line:

- Enter time t with AUM $= cash_{t-1} + bonds_{t-1} v_t$, where $bonds_{t-1}$ is the number of units of bonds held, and v_t is the fundamental value per unit.
- Get dollar outflow f_t (or inflow $-f_t$).
- Next period, at time $t+1$, if your redemptions exceed your cash, you have to liquidate enough

illiquid bonds to meet that need, which may be costly if everyone else is selling too.

- So the trade-off at time t is between buying more bonds which have a higher expected return than cash, but that increases your market risk as well as the chance of having insufficient cash and paying higher bond liquidation costs next period.

- At time t choose how many extra bonds to buy to maximise $E[cash_{t+1} + bonds_{t+1}v_{t+1}] - \lambda_t(p_t bonds_t)^2$, your risk-adjusted expected AUM next period after any liquidations.

2.4 Funds' utility

Funds maximise their utility, specified as:

$$U_t \equiv E_t \left[\underbrace{cash_{t+1} + bonds_{t+1}v_{t+1}}_{AUM_t} \right] - \underbrace{\lambda_t(p_t bonds_t)^2}_{\text{penalty for risk}} \tag{2}$$

If their risk-aversion coefficient $\lambda_t = 0$, or they don't hold any risky bonds, they are trying to maximise their assets under management (AUM), which is the sum of their cash and bond holdings, where their bond holdings are evaluated at their fundamental value rather than their price, to filter out any temporary deviations in the price from fundamental value due to price pressure if aggregate trading Q_t is not zero. They could be trying to maximise their AUM because they are paid a fixed percentage of it as a management fee at the end of the period. But they are risk-averse, so if their risk-aversion coefficient $\lambda_t 0$ is strictly positive, there is a risk penalty function proportional to the value of their risky bond holdings over the next period. This is in the same spirit as the more-conventional mean-variance set-up with risk penalty function $\lambda_t Var_t[AUM_{t+1}]$ or a value-at-risk constraint. But our current set-up is a reduced-form way of introducing risk-aversion, while still allowing closed-form solutions.

2.5 Trading

There are 2 rounds of trading. We work backwards from the final trade time.

2.5.1 Final period, time $t+1$

The fund enters time $t+1$ with $cash_t$, the same amount of cash as it had last period, since interest rates are assumed to be zero. It then receives fund outflows f_{t+1} or inflows f_{t+1}. If the fund has positive total net inflows, or sufficient cash to meet its total net outflows, it doesn't trade any bonds, and just uses its cash to pay out its net outflows, i.e. if $cash_t \geq f_{t+1}$ then $q_{t+1} = 0$. Cash is assumed to be perfectly liquid, so there is no transaction cost for this, and its cash position becomes $cash_{t+1} = cash_t - f_{t+1}$.

If the fund instead has a cash shortfall, because its cash is insufficient to cover its total net outflows, i.e. $cash_t < f_{t+1}$, then the fund drains its cash reserves, i.e. $cash_{t+1} = 0$, and sells just enough bonds to exactly cover that shortfall. We denote the amount they sell in this case as $-q_{t+1}^{-}$, given by:

$$-q_{t+1}^{-} = \frac{f_{t+1} - cash_t}{p_{t+1}} \tag{3}$$

So at time $t+1$, after trading, the fund ends up with this many units of the bond:

$$\begin{aligned} bonds_{t+1} &= bonds_{t-1} + q_t + q_{t+1} && (4) \\ &= bonds_{t-1} + q_t - \left(\frac{f_{t+1} - cash_t}{p_{t+1}} \right) 1_{cash_t < f_{t+1}} && (5) \end{aligned}$$

and this much cash:

$$\begin{aligned} cash_{t+1} &= (cash_t - f_{t+1})\, 1_{cash_t \geq f_{t+1}} && (6) \\ &= (cash_{t-1} - f_t - p_t q_t - f_{t+1})\, 1_{cash_t \geq f_{t+1}} && (7) \end{aligned}$$

2.5.2 First period: time t

In the appendix we show how we can re-write the fund's utility function by conditioning on its investor flows at time $t+1$:

$$
\begin{aligned}
& E_t\left[cash_{t+1} + bonds_{t+1}v_{t+1}\right] - \lambda_t(p_t bonds_t)^2 && (8)\\
= \;& E_t\left[E_t\left[cash_{t+1} + bonds_{t+1}v_{t+1}|f_{t+1}\right]\right] - \lambda_t(p_t bonds_t)^2 && (9)\\
= \;& \underbrace{cash_t - E_t[f_{t+1}] + (bonds_{t-1} + q_t)\, E_t[v_{t+1}]}_{\text{expected AUM if no cash shortfall}} - \underbrace{\lambda_t(p_t(bonds_{t-1} + q_t))^2}_{\text{penalty for risk}} \\
& - \underbrace{E_t\left[(p_{t+1} - v_{t+1})\, q^-_{t+1} \mid cash_t < f_{t+1}\right]}_{\text{expected total haircut if shortfall}} && (10)
\end{aligned}
$$

We see the trade-offs that the fund faces at the first round of trading at time t, where buying more (or selling less) of the bond, i.e. a higher q_t:

1. increases expected bond AUM, both through more units and since those units of the bond have a higher expected return than the cash which was used to buy them;
2. increases the penalty for risk over the next period (assuming long bonds entering time t);
3. decreases cash AUM;
4. increases the probability of cash shortfall next period;
5. increases the magnitude of the expected liquidity cost if there is a cash shortfall (since funds are by assumption only selling or not trading at the final time $t+1$, i.e. $Q_{t+1} < 0$, the price at which the fund sells, $p_{t+1} = v_{t+1} + c_{t+1}Q_{t+1}$, will be less than fundamental value).

To get a closed-form solution for q_t, we target an objective function which is a negative quadratic in q_t, and thus has a unique maximum. So we assume the investor flows are uniformly distributed, and independent of everything else:

$$f_{t+1} \sim Uniform\left[\underline{f}, \bar{f}\right] \tag{11}$$

The range of fund flow values need not be symmetrical around 0.

To compute the first order condition and solve for q_t, we need the sensitivities to q_t:

$$cash_t = cash_{t-1} - f_t - p_t q_t \quad \Rightarrow \quad \frac{\partial cash_t}{\partial q_t} = -p_t < 0 \tag{12}$$

$$P[cash_t < f_{t+1}] = \frac{\bar{f} - cash_t}{\bar{f} - \underline{f}} \quad \Rightarrow \quad \frac{\partial P[cash_t < f_{t+1}]}{\partial q_t} = \frac{p_t}{\bar{f} - \underline{f}} > 0 \tag{13}$$

$$q_{t+1}^{-} = \frac{cash_t - f_{t+1}}{p_{t+1}} \quad \Rightarrow \quad \frac{\partial q_{t+1}^{-}}{\partial q_t} = -\frac{p_t}{p_{t+1}} < 0 \tag{14}$$

The first order condition with respect to q_t is given by:

$$\begin{aligned} 0 \quad = \quad & E_t[v_{t+1}] - p_t - 2\lambda_t p_t^2 (bonds_{t-1} + q_t) \\ & - \frac{p_t}{\bar{f} - \underline{f}} \left(cash_{t-1} - f_t - p_t q_t - \bar{f}\right) E_t\left[\frac{c_{t+1} Q_{t+1}}{p_{t+1}}\right] \end{aligned} \tag{15}$$

If $c_{t+1} = 0$ or $Q_{t+1} = 0$, then $p_{t+1} = v_{t+1}$, and there's no transaction cost for liquidating bonds at time $t+1$, and the fund optimally holds the following number of units of the bond after trading at time t:

$$bonds_t = q_t + bonds_{t-1} \quad = \quad \frac{E_t[v_{t+1}] - p_t}{2\lambda_t p_t^2} \tag{16}$$

More generally, substituting in the specification of the price, and simplifying, the dollar amount spent on bonds becomes:

$$p_t q_t \quad = \quad \frac{\overbrace{E_t[v_{t+1}/p_t] - 1}^{\text{expected return}} - \overbrace{2\lambda_t p_t bonds_{t-1}}^{\text{extra risk}} - \overbrace{\frac{1}{\bar{f} - \underline{f}}\left(cash_{t-1} - f_t - \bar{f}\right)}^{\text{expected shortfall at time } t+1} \overbrace{E_t\left[\frac{c_{t+1} Q_{t+1}}{p_{t+1}}\right]}^{\text{\% illiquidity}}}{2\lambda_t - \frac{1}{\bar{f}-\underline{f}} E_t\left[\frac{c_{t+1} Q_{t+1}}{p_{t+1}}\right]} \tag{17}$$

Note that some of this trading is induced by investors' fund flows at time t: if there are net inflows then bonds need to be bought, and if there are net outflows then bonds need to be sold, all else equal.

Intuitively, from the fund's trade-offs when trading highlighted earlier, this amount is:

- increasing in the bond's expected return (as this makes the bond more attractive, increasing expected AUM);

- increasing in the fund's cash holding (as this both reduces the chance of a cash shortfall next period, and reduces the expected total bond liquidation cost if there is a cash shortfall, since fewer bonds would need to be sold);

- decreasing in the fund's risk-aversion (as this makes buying more risky bonds relatively less attractive compared to leaving it as risk-free cash);

- decreasing in the bond's current price (i.e. there is a downward-sloping demand curve, and writing the price as $v_t + c_t Q_t$ we see that bond buying is equivalently decreasing in other funds' current net buying, especially when the current liquidity cost is high);

- decreasing in the bond's price risk (as this makes risky bonds less attractive to risk-averse funds, who pay a penalty proportional to the square of the number of units of the bond holding);

- decreasing in the fund's expected future outflow (as higher future flows both increases the chance of a cash shortfall next period, and increases the expected total bond liquidation transaction cost if there is a cash shortfall, since more bonds would need to be sold);

- decreasing in the expected future liquidity cost when selling (as buying more bonds increases both the chance of a cash shortfall next period, and the expected total bond liquidation transaction cost if there is a shortfall next period, whether c_t or Q_t or both are higher).

2.6 Market clearing

2.6.1 Final period: time $t+1$

The total net buying at time $t+1$ is given by:

$$Q_{t+1} = \sum_f q^f_{t+1} \tag{18}$$

$$= \sum_f \left(\frac{cash^f_t - f^f_{t+1}}{p_{t+1}} \right)^- \tag{19}$$

$$= \frac{1}{v_{t+1} + c_{t+1} Q_{t+1}} \sum_f \left(cash^f_t - f^f_{t+1} \right)^- \tag{20}$$

assuming the price is positive. This is equivalent to the following quadratic equation in Q_{t+1}:

$$c_{t+1} Q^2_{t+1} + v_{t+1} Q_{t+1} - \sum_f \left(cash^f_t - f^f_{t+1} \right)^- = 0 \tag{21}$$

whose solution is:

$$Q_{t+1} = \frac{-v_{t+1} + \sqrt{v^2_{t+1} + 4c_{t+1} \sum_f \left(cash^f_t - f^f_{t+1} \right)^-}}{2c_{t+1}} \leq 0 \tag{22}$$

Since individual funds are only selling or not trading, not buying, at time $t+1$, in aggregate they are also only selling or not buying, so $Q_{t+1} \leq 0$.

From the solution we see that there is a maximum total cash shortfall of $\frac{v^2_{t+1}}{4c_{t+1}}$ which can sustain an equilibrium: beyond that, the price pressure from selling makes the haircut so large that it doesn't generate enough cash to meet fund redemptions. For instance, if $v_{t+1} = \$100$ and $c_{t+1} = 5.6 \times 10^{-7}$ (calibrated from the pooled average haircut in the data), then the maximum total cash shortfall across funds that can be raised by selling the bond is \$4.5billion, which is very unlikely to be reached for an individual bond issue. But it could be more of a problem for bonds whose price is very sensitive to trading. This is one reason why, empirically, funds who hold multiple bonds do not concentrate their selling in a single bond to finance redemptions, as splitting the selling across multiple bonds would reduce the average haircut.

The price is positive if and only if $p_{t+1} \equiv v_{t+1} + c_{t+1}Q_{t+1} > 0$, so $Q_{t+1} > -\frac{v_{t+1}}{c_{t+1}} = \frac{-v_{t+1} - \sqrt{v_{t+1}^2}}{2c_{t+1}}$, which holds for both roots of the quadratic. Although theoretically there are two equilibria, with funds either selling a smaller quantity at a smaller haircut, or a larger quantity at a larger haircut, only one is plausible. For example, if $v_{t+1} = \$100$, $c_{t+1} = 5.6 \times 10^{-7}$, and the total cash shortfall across funds is \$100million, then (p_{t+1}, Q_{t+1}) can theoretically be (\$0.56, -180million units), but is much more plausibly (\$99.44, -1million units), with the bond's price close to its fundamental value. Choosing the solution the fund manager would optimally choose, where the haircut is smaller and therefore the AUM is larger, eliminates the negative root of the quadratic where the price is implausible.

The bond's price haircut as a percentage of the bond's fundamental value is:

$$-\frac{c_{t+1}Q_{t+1}}{v_{t+1}} = \frac{1 - \sqrt{1 + 4c_{t+1}/v_{t+1}^2 \sum_f \left(cash_t^f - f_{t+1}^f\right)^-}}{2} \geq 0 \tag{23}$$

Intuitively, both the total number of units sold by funds to cover any cash shortfall, and the resulting bond price haircut at time $t+1$, are:

- decreasing in the funds' fundamental value, as fewer bonds need to be sold if the price for each is higher;
- increasing in the bond price's sensitivity to aggregate selling, as more bonds need to sold if aggregate selling depresses the price more;
- increasing in funds' aggregate cash shortfall (increasing in funds' total net outflows, and decreasing in funds' total cash), as more bonds would need to be sold to cover fund outflows, leading to a larger haircut.

These patterns for funds' selling and the bond price's haircut at time $t+1$ are depicted in Figure

6, in the top and bottom row of graphs, respectively.

2.6.2 First period: time t

The total net buying at time t is given by:

$$
\begin{aligned}
Q_t &= \sum_f q_t^f &(24)\\
&= \sum_f \frac{E_t[v_{t+1}/p_t] - 1 - 2\lambda_t^f p_t bonds_{t-1}^f - \frac{1}{\bar{f}^f - \underline{f}^f}\left(cash_{t-1}^f - f_t^f - \bar{f}^f\right) E_t\left[\frac{c_{t+1}Q_{t+1}}{p_{t+1}}\right]}{p_t\left(2\lambda_t^f - \frac{1}{\bar{f}^f - \underline{f}^f} E_t\left[\frac{c_{t+1}Q_{t+1}}{p_{t+1}}\right]\right)} &(25)
\end{aligned}
$$

If the funds are homogeneous along the following dimensions: $\lambda_t^f = \lambda_t$, $\bar{f}^f = \bar{f}$, $\underline{f}^f = \underline{f}$, the expected return (from traded price p_t at time t to fundamental value v_{t+1} at time $t+1$) becomes:

$$
\begin{aligned}
E_t\left[\frac{v_{t+1}}{p_t}\right] - 1 &= 2\lambda_t p_t \sum_f bonds_{t-1}^f + \frac{1}{\bar{f} - \underline{f}} E_t\left[\frac{c_{t+1}Q_{t+1}}{p_{t+1}}\right] \sum_f \left(cash_{t-1}^f - f_t^f - \bar{f}\right)\\
&\quad + Q_t p_t \left(2\lambda_t - \frac{1}{\bar{f} - \underline{f}} E_t\left[\frac{c_{t+1}Q_{t+1}}{p_{t+1}}\right]\right) &(26)
\end{aligned}
$$

So the bond's expected return is:

- increasing in the bond's risk;
- decreasing in funds' total cash;
- increasing in funds' current outflows, expected future outflows, and cash shortfall.

The haircut at time t is:

$$
\frac{c_t Q_t}{p_t} = c_t \sum_f \frac{E_t[v_{t+1}/p_t] - 1 - 2\lambda_t p_t bonds_{t-1}^f - \frac{1}{\bar{f} - \underline{f}}\left(cash_{t-1}^f - f_t - \bar{f}\right) E_t\left[\frac{c_{t+1}Q_{t+1}}{p_{t+1}}\right]}{p_t^2\left(2\lambda_t - \frac{1}{\bar{f} - \underline{f}} E_t\left[\frac{c_{t+1}Q_{t+1}}{p_{t+1}}\right]\right)} \qquad (27)
$$

2.7 Liquidity value-at-risk

A fund's expected total liquidity cost given a cash shortfall from high fund outflows can be computed by conditioning on whether there is a cash shortfall:

$$
\begin{aligned}
E_t\,[\text{total haircut}] &= P_t[\text{cash shortfall}]E_t\,[(\text{haircut per unit}) \times (\text{units sold})\,|\text{shortfall}] \quad (28)\\
&= P_t[f_{t+1} > cash_t]E_t\left[(\text{haircut per unit}) \times \frac{\text{shortfall}}{p_{t+1}}\right] \quad (29)\\
&= \left(\frac{\bar{f} - cash_t}{\bar{f} - \underline{f}}\right) E_t\left[c_{t+1}Q_{t+1}\left(\frac{(f_{t+1} - cash_t)^+}{v_{t+1} + c_{t+1}Q_{t+1}}\right)\right] \quad (30)\\
&\approx \left(\frac{\bar{f} - cash_t}{\bar{f} - \underline{f}}\right) E_t\left[\frac{c_{t+1}Q_{t+1}}{v_{t+1}}(f_{t+1} - cash_t)^+\right] \quad (31)
\end{aligned}
$$

2.8 Numerically solving the model

Each of the expected haircut $-E_t[c_{t+1}Q_{t+1}/p_{t+1}]$, trading $p_t q_t$ and the bond's expected return $E_t[v_{t+1}/p_t] - 1$, depend on the other two. We solve the fixed point problem to find values of each such that equations (17), (22), and (23) all hold simultaneously.

2.8.1 Calibrating the model

We use moments of the data to calibrate the model. The mean percentage liquidity cost is 0.29%. If c_t is constant, then 0.29% is the mean of $\frac{c|Q_t|}{v_t} = cE\left[\frac{|Q_t|}{v_t}\right]$ if Q_t and v_t are independent. $E\left[\frac{|Q_t|}{v_t}\right] \approx 0.0031 \times (3,000 million \times 1,000 \times 0.56)/100^2 = 520,800$. Then our calibrated $c = 0.29\%/520,800 = 0.56\%$, with Q_t in millions of dollars. We set TNA for each fund to \$1.448 billion, assume there are 1,000 funds, set $v_t = v_{t+1} =$ \$100, $f_{t+1} \sim U[-3.49\%, 3.55\%]$, $cash_{t-1} = 1.5\%$ of TNA, $bonds_t$ = 51.7% of TNA, set the bond's expected return to $E[v_{t+1}/p_t] - 1 = 0.58\%$, and $\lambda = 10^{-10}$.

2.8.2 Bond trading, haircuts, and expected returns

Thinking about future aggregate fund outflows, aggregate cash holdings, and aggregate cash shortfalls, the partial equilibrium intuition is that as expected aggregate fund outflows at time $t+1$

increase and/or aggregate cash holdings at time t decrease, or the expected aggregate cash shortfall at time $t+1$ increases, the expected size of the bond price haircut will increase, as funds are more likely to be selling more at time $t+1$. And so funds need to hold more cash going into time $t+1$ by buying less, or selling more, bonds at time t, in anticipation. The general equilibrium effect mitigates some, but not all, of this effect, as we see in Figure 7: because the other funds also anticipate the increased size of their own cash shortfalls and haircut as expected aggregate fund outflows at time $t+1$ increase and/or aggregate cash holdings decrease, or the expected aggregate cash shortfall increases, they also increase their own cash positions more at time t, by selling less / buying more bonds at time t than if they hadn't made that adjustment, and therefore the increase in haircut size at time $t+1$, and extra precautionary saving at time t, is mitigated. More selling at time t reduces the price and thus also increases the haircut at time t, as funds trade off the uncertainty of forced selling at time $t+1$, with the choice of selling at time t with a possibly more favourable haircut. So the haircut at t and expected haircut at $t+1$ are positively correlated due to this substitution effect.

As the aggregate expected outflow decreases and/or aggregate cash holding increases, the size of a cash shortfall and expected haircut tend to zero, which is why the curves flatten out, with little change in precautionary saving needed. The dashed lines denote the limiting case where the expected haircut is zero. If the expected aggregate outflow increases too much and/or the aggregate cash holding decreases too much, there is no equilibrium possible, as the cash shortfall becomes so large that it cannot be recovered from selling bonds, as the haircut would be too large because of the large volume of simultaneous selling by many funds.

Figure 8 shows the effect of varying the risk penalty parameter λ, the mean cash holding, and the volatility of those outflows, on trading, haircuts, and returns. The left 4 columns show the effect of varying aggregate cash holdings. The right column shows the effect of fixing the cash holding of all other funds to 1.5% of total net assets, while varying one individual fund's cash holding. Comparing the top row to the middle row, we see that as the risk penalty increases, there is more aggregate bond selling at time t, which increases the expected return from time t to $t+1$, due to a lower price at time t and no change in the fundamental value at time $t+1$. Moving from the middle row to the bottom row, we narrow the range of outflow values from [-3.49%, 3.55%] to [-1%, 1%]. For high levels of cash, this reduces the probability of a cash shortfall to close to zero, and so the expected haircut at time $t+1$ also approaches zero, since there would be no required selling. For the same reason, other funds' aggregate trading is unaffected by aggregate cash when it is sufficiently high. But if the aggregate cash is low enough such that there is some chance of a cash shortfall because the current cash holding is less than the maximum cash outflow, then there is more selling at time t, lowering the time-t price, and increasing the time-t haircut and the expected return from time t to $t+1$. Varying the the individual fund's cash in the right column has the same effect on its trading as the other funds, except when cash is very low, selling can decrease slightly, if the haircut gets too high.

3 Data

Data on bond liquidity costs, credit ratings, and trade volume are from TRACE / Mergent FISD on WRDS. Data on bond mutual funds' holdings is from Morningstar. We exclude ultra-short-term and index funds, so we focus only on active long-term open-end corporate bond US mutual funds. As a sanity check, total net assets and the sum of the market value of holdings should be identical. So if the magnitude of the difference between the total net assets and the sum of the market value of holdings is greater than 18% (the 90th percentile), we remove the fund from the sample.

3.1 Cash

The computation of cash from Morningstar is delicate, and requires some thought and re-categorization. In months where a fund holds derivatives, but no cash-derivatives, we reclassify cash and cash-currency as cash-derivatives. Also reclassified as cash-derivatives are items originally classified as cash or cash-currency which include the names 'offset', 'broker', 'margin', 'ccp', 'fut', 'unsettled', ‘der’, ‘otc’, ‘future“, ‘haircut’, ‘rrp’, ‘swap’, ‘collateral’, ‘cme’, ‘deriv’, ‘call’, ‘put’, or ‘committed’. Holdings which are themselves mutual funds are interpreted as money-market mutual funds and are reclassified as cash if they include the following in their name: ‘fidelity revere str tr’, ‘goldman sachs fs government instl’, ‘liquidity’, ‘fedfund’, ‘mm fds’, ‘lqudty’, ‘mmkt’, ‘government obligs’, ‘money market’, ‘cash mgmt’, ‘cash’, ‘obl’, ‘govtt rsrv’, ‘treasury bd’, ‘short’, ‘shrt-trm’, ‘gov. reserve’, or ‘liquid’.

3.2 Derivatives

Contrary to traditional thoughts on mutual funds, many hold derivatives as part of their portfolio. Data on funds’ derivative holdings is from SEC filings via form N-PORT. There are 6 asset categories (commodity, credit, equity, foreign exchange, interest rate, and other), and for each there are 7 derivative instrument categories (forward, future, option, swap, swaption, warrant, other), which we aggregate.

For derivatives we focus on the period July 2019 to June 2020, which covers the pre-Covid period up to and including January 2020, the Covid outbreak which we classify as February-March 2020, and the market recovery from April 2020 onwards. Funds are classified as ‘hedging’ or ‘amplifying’ based on the correlation between their derivative and non-derivative returns in the pre-Covid period. Following Kaniel and Wang (2021) we compute funds’ derivative-induced return (DIR) as:

$$DIR = \frac{\text{realized gain + unrealized appreciation - lag(unrealized appreciation)}}{\text{lag(TNA)}} \tag{32}$$

The residual non-derivative induced return (non-DIR) is computed by subtracting the DIR from the total fund return.

4 Empirical analysis

We see from Figure 2 that the correlation between funds' returns from derivatives and non-derivative holdings is quite symmetrical and approximately normally distributed. The mean and median correlations are -0.15 and -0.19, respectively. We rank funds with at least 3 returns in their time-series by this correlation in the pre-Covid period, and classify funds which hold at least one derivative at at least one point in time as either 'hedging' (the lowest / most negative correlation tercile) or 'amplifying' (the highest correlation tercile), following Kaniel and Wang (2021) who analyse equity mutual funds. The distribution of correlations is quite different between bond and equity mutual funds; for bond funds it is much more typical to have correlations close to zero, whereas Kaniel and Wang (2021) show that for equity funds the distribution is more bimodal, with a lot of mass near the extreme correlations of ± 1. Our cut-off correlation values for hedging and amplifying are negative (-0.55) and positive (0.10), respectively, so this classification allows the interpretation that hedging funds are typically using derivatives to de-lever their portfolio returns, while amplifying funds are using them more to lever up.

The classification of funds is checked by looking at the market beta of fund returns in Table 4. We regress fund returns for hedging, amplifying, and no-derivative funds on the Vanguard Total Bond Market Index. We see that the beta is very similar for amplifying and hedging funds (0.74), and slightly higher for no-derivative funds (0.80). All the betas are less than one, so all three groups have less systematic risk than the benchmark index. None of the groups have significant alpha. Table 5 shows that on average amplifying funds have higher expense ratios and lower total net assets compared to hedging funds.

4.1 Summary statistics

Summary statistics are provided in Table 1 (whole sample), Table 2 (Global Financial Crisis of September 2008), and Table 3 (Covid outbreak of March 2020). We see that the outbreak of Covid-19 was an even more severe period than the Financial Crisis across a number of dimensions.

The median liquidity cost jumped from 19 basis points across all time periods to 46 basis points in September 2008 during the Financial Crisis and 49 basis points at the start of the Covid-19 outbreak in March 2020. Bond returns were typically positive overall, with a median monthly return of 0.42%, but with a large cross-sectional standard deviation of 4.3%, and became very negative and more variable in the crisis periods, with median returns of -3.44% and -5.39%, and standard deviations of 8.3% and 11.08%, for the GFC and Covid-19 outbreak periods, respectively. Fund flows were close to zero overall, but become negative in the crisis periods, with medians of -1.12% and -3.25% at the starts of the GFC and Covid-19, respectively.

4.2 Holdings

Tables 6 and A1 show the proportions of mutual fund holdings in different asset classes for funds whose derivative positions amplify or hedge their portfolio returns, and for funds who never hold derivatives, averaged across quarterly and monthly data, respectively.

4.2.1 Cash

On average hedging and amplifying funds hold negative cash positions, while no-derivative funds hold positive cash. But there is a lot of cross-sectional variation between funds in all three fund strategies.

4.2.2 Government and Corporate Bonds

Amplifying funds held a much larger proportion of their portfolios in corporate bonds than hedging funds, but a lower proportion in government bonds. Since corporate bonds are almost always riskier than government bonds in the US, this suggests how different fund types use both bond and derivative strategies to manage the market risk of their portfolios, with hedging funds using derivatives to reduce the risk of their already less risky bond holdings, and amplifying funds using derivatives to increase the risk of their already riskier bond holdings.

4.2.3 Derivatives

Amplifying funds held long positions in derivatives on average during the time period, but hedging funds held short positions on average. The cross-sectional variation in derivative holdings was much higher for hedging funds than amplifying funds. Derivative strategies also appear not to be static, and the classification of whether funds are hedging or amplifying may be time-varying. 'Cash-derivatives' denotes cash specifically set aside for funds' derivative holdings.

4.3 Fund flows and probability of a cash shortfall

Table 5 shows that hedging funds had higher, and more volatile, net fund inflows than hedging funds. Equation (28) from the model show that the probability of a cash shortfall due to investor outflows affects funds' trading and the liquidity-value-at-risk, respectively. In the model we assumed that fund flows had a uniform distribution to be able to solve it in closed form. But empirically we see from Figure 3 that the distribution pooled across all funds and all time is closer to normally distributed, though with excess kurtosis. The t-stat is a useful heuristic for estimating the probability of a cash shortfall after paying out redemptions, and if we approximate the distribution of fund flows as normal, then we can estimate the implied probability of a fund having a cash shortfall as:

$$\begin{aligned} P_t\left[\text{cash shortfall at time } t+1\right] &\equiv P_t\left[cash_t < f_{t+1}\right] & (33)\\ &= P_t\left[\frac{cash_t - E_t[f_{t+1}]}{SD_t[f_{t+1}]} < \frac{f_{t+1} - E_t[f_{t+1}]}{SD_t[f_{t+1}]}\right] & (34)\\ &\approx 1 - \Phi\left(\frac{cash_t - E_t[f_{t+1}]}{SD_t[f_{t+1}]}\right) & (35)\end{aligned}$$

For the hedging and amplifying funds, we can compute how many standard deviations the sum of mean cash holdings and mean net fund inflows are from zero. The t-stat for amplifying funds = (-0.5-0.415)/4.355 = -0.21, corresponding to a 58% probability of a cash shortfall, and the t-stat for hedging funds = (-1.1+0.647)/4.778 = -0.09, corresponding to a 54% probability of a cash shortfall.

These computed probabilities are only part of the picture of funds' liquidity risk management, as the market risk and liquidity risk are different across fund types and across time, and there is likely a fund-specific component to the conditional distributions of fund flows. Since hedging funds have less systematic bond market risk, they may be more comfortable with a higher cash shortfall probability, if ex ante they may have felt that their fund returns were somewhat protected on the downside and so they were somewhat insulated from fund outflows when the market fell, although ex post this was not the case.

Figure 4 plots the expected portfolio liquidation cost as a function of a fund's cash proportion and the bond's liquidity cost, assuming that investor fund flows are normally distributed with the same mean and standard deviation as those for funds which never hold derivatives. The vertical lines mark the mean proportion of cash for a no-derivative fund, and a 95% confidence interval around it, to give a sense of where funds are likely to operate. Intuitively, we see that the higher the cash position, the lower the expected liquidation cost, as both the probability of a cash shortfall, and the magnitude of liquidation cost given a shortfall, are lower. The higher the bond transaction cost, the higher the expected liquidation cost as a proportion of AUM, but the magnitude is much smaller, as only a portion of the portfolio needs to be liquidated.

4.4 Trading, liquidity, and bond returns

4.4.1 Bond trading

A prediction from the model is that funds' trading, in the final period most starkly, is affected by the cash shortfall that they face in meeting their investors' redemption needs. In the final period of the model, they use up all their liquid cash first, before selling the less liquid bond, which comes with transaction costs, so the model imposes a pecking order of selling in order of liquidity by assumption. More generally, funds may not want to completely empty their cash reserves, but we expect to see their trading explained to some extent at least by a pecking order from cash to corporate bonds when they have investor outflows.

Table 7 shows that mutual funds' corporate bond trading is positively correlated with fund flows, but less so when their cash holding is larger. We regress corporate bond trading, at the bond level, measured by the percentage increase in the number of units held from one month to the next, on a number of factors predicted by the theoretical model. We include monthly fixed effects and standard errors are clustered at the fund level. We see that trading is positively and significantly related to fund flows, i.e. higher net outflows are at least partly financed by selling larger quantities of corporate bonds, and higher net inflows lead to more corporate bond buying. Buying is negatively and significantly related to the interaction of fund outflows with cash, i.e. there is even more selling of corporate bonds when a funds' cash reserves are low, because it becomes more necessary to finance those fund outflows by selling corporate bonds, rather than just using cash reserves. We see that cash only significantly affects selling when it is interacted with outflows, so for instance low cash is only a concern for funds, and influences their trading, if outflows are simultaneously relatively high. The results for outflows are consistent with the predictions of the model, where the only flows at time $t + 1$ are outflows: Figures 7 and 8 show there is more selling when outflows are higher, holding cash reserves constant, or cash reserves are lower, holding flows constant, respectively.

The illiquidity of the security, and its interaction with fund flows, do not significantly affect trading, but this may be because it is correlated with the bond's interest rate risk and credit risk, proxied by the bond's duration and an indicator for whether the bond is investment grade or high yield, respectively. Duration is also not a significant predictor of trading, but investment grade bonds are sold more (or bought less) than high yield bonds, both for the outflows and inflows samples.

Table 8 splits the outflows sample into amplifying funds, hedging funds, and funds with no derivative holdings. We see that both amplifying and hedging funds' trading of corporate bonds is sensitive to the interaction of fund flows with cash holdings. Hedging funds typically attract investor inflows while amplifying funds have outflows on average, but both hedging and amplifying funds have a cash position which is negative on average, and hold insufficient cash to meet investor redemptions. The trading of no-derivative funds, who typically hold enough cash to meet their redemptions, is not significantly sensitive to that interaction.

Table 9 shows that mutual funds' government bond trading is also positively correlated with fund flows, but now the interaction of flows with cash is insignificant. This may be that when fund flows are negative, it's a time when funds not only need to raise cash but also want to reduce the market risk of their portfolio, and so trading corporate bonds rather than government bonds is a way to combine both. Duration is significant and positive, as government bonds' market risk is dominated by interest rate risk rather than credit risk. The greater the duration, the more the government bond is sold if there is a fund outflow, so funds are not just funding their outflows by liquidating government bonds, but simultaneously reducing the risk of their portfolios. For inflows, the greater the duration, the more the government bond is bought if there is a fund inflow, so funds are simultaneously increasing the risk of their portfolios.

Table 10 digs deeper into the interaction of cash and investor fund flows. It highlights the pecking order from cash to corporate bonds in the event of liquidation, depending on the magnitude of fund flows as a percentage of cash reserves. We separately regress corporate bond trading and cash trading on fund flows, stratified by what proportion those flows represent in terms of funds' cash reserves. It shows that bond (cash) trading is much more (less) sensitive to fund flows when redemptions are large relative to cash. The statistical significance of these results is correlated with their magnitudes, with larger (smaller) t-statistics for bond (cash) trading when fund flows are larger.

4.4.2 Liquidity costs

In the model, the price is assumed to be $p_t = v_t + c_t Q_t$, where v_t is the bond's fundamental value, and its liquidity cost $c_t Q_t$ is the product of a non-trading component c_t and aggregate trading (Q_t is negative for net selling). This highlights the role of price pressure, motivated by e.g. the model in Randall (2021b) where dealers in an OTC market have limited risk-bearing capacity/tolerance, and so if they are at their optimal inventory level, to trade in larger size they require compensation for the extra risk that involves in the corporate bond market where they may not be able to offload those trades for several days, particularly a concern for them when the bonds have high credit risk, and in crisis periods when they have tighter market risk and capital limits.

Figure 5 shows that liquidity costs, and the change in liquidity costs, spiked in the GFC and Covid-19 periods. The level was higher in the GFC, but the change was higher at the outbreak of Covid-19. So, proportional change relative to the level is even higher during the Covid-19 outbreak compared to the GFC.

In Table 11 we regress liquidity costs on aggregate trading, aggregate cash shortfall, measures of bond trading frequency, trade volume, and bond risk. Liquidity costs are measured as the difference between the average price that customers buy from, and sell to, a dealer within a month, divided by two, for each bond. This is an estimate for the average 'markup' from the dealer to the customer. Bond trading frequency is proxied by the amount of the bond still outstanding since issuance, and the log of dollar trade volume. Bond risk is proxied by lagged duration to measure interest rate risk, and an investment grade credit rating dummy to measure credit risk. We include monthly fixed effects, and standard errors are also clustered at the monthly level. The table shows that corporate bonds' liquidity costs increase when funds are on average selling that security, that is when the aggregate mean trade is negative. Aggregate mean trade is computed as the percentage increase in funds' bond holdings (in number of shares) averaged across all funds. The effect of funds' trading on liquidity costs are an order of magnitude larger at the Covid-19 onset in March 2020, and even stronger in the Financial Crisis in September 2008, when bond dealers had less risk appetite and capacity, and raised the cost of trading. During the Covid-19 outbreak, funds' aggregate cash shortfall becomes statistically significant, with a higher average shortfall increasing liquidity costs. The results are consistent with the predictions of the model: Figures 7 and 8 show that more aggregate selling and higher aggregate cash shortfall, because of higher expected outflows and/or low cash reserves, are associated with higher haircuts.

Table 12 shows that changes in corporate bonds' liquidity costs are also negatively related to funds' trading. As with the level of liquidity costs, the change in liquidity costs is significantly affected by funds' cash shortfall in the Covid-19 period.

The significance of aggregate trading and aggregate cash shortfall highlights the systemic importance of bond mutual funds in the corporate bond market, with funds needing to account for the holdings and trading of their peers.

4.4.3 Corporate bond returns

Figure 5 shows corporate bond returns over time, with particularly large negative returns in the crisis periods of the GFC and the outbreak of Covid-19.

In unreported results, in the pre-Covid period bond returns are quite similar across the three fund groups, at around 60 basis points per month. But amplifying funds fared much better than hedging funds at the start of the Covid outbreak (+0.47% versus -0.55% in February 2020, and -6.67% versus -9.57% in March 2020), while hedging funds had higher returns in the recovery period (+2.69% versus +2.31%). The mean return of funds (0.37% monthly) is very similar to that of their non-derivative holdings (0.39%), whereas that of the derivatives is only 0.0023%. However derivatives represent a much larger component of funds' return standard deviation: 1.2% monthly versus 3.07% for the non-derivatives, and 2.78% overall.

Table 13 shows that corporate bond returns are positively related to funds' trading in the full sample. This is related to equation (26) from the model on expected returns which predicted this result. The model also predicts that funds' cash shortfall should be negatively related to expected bond returns, which it is, but only significantly so in the Covid-19 period.

5 Conclusion

We show, both theoretically and empirically, that aggregate measures of mutual fund trading, and their cash reserves relative to fund flows are systemically important to corporate bond liquidity and expected returns. Funds have to consider not only their own cash position, expected fund flows, and unconditional liquidity costs, but the cash positions of the aggregate mutual fund industry, aggregate expected fund flows, and liquidity costs conditional on the aggregate trading of the market. The results are particularly strong in the large market downturn periods of the Global Financial Crisis and the outbreak of the Covid-19 pandemic.

We are also the first to analyze bond mutual funds' use of derivatives to hedge or amplify their returns, using funds' SEC filings. We document large variation in hedge fund strategies, with some funds using those derivatives to hedge their returns, some to amplify them, and many choosing not to use derivatives at all. It will be interesting to explore further the institutional reasons why there is such a diversity of strategy.

Our model builds our intuition on the trade-offs that mutual funds face when trading bonds: buying more bonds with cash increases expected portfolio return, but at the cost of greater market risk, and it increases both the probability of a future cash shortfall and the expected liquidation cost in the case of large investor redemption requests. We plan to develop the model further, by extending from cash and a single bond to many assets, including derivatives which can hedge or amplify both the risk and return of funds' portfolios, to further understand mutual funds' derivative strategies we have documented empirically.

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Figure 2: **Correlations between Derivative Returns and Non-Derivative Returns** This figure plots the cross-sectional distribution of time-series correlations between monthly derivative returns and non-derivative returns between July 2019 and January 2020.

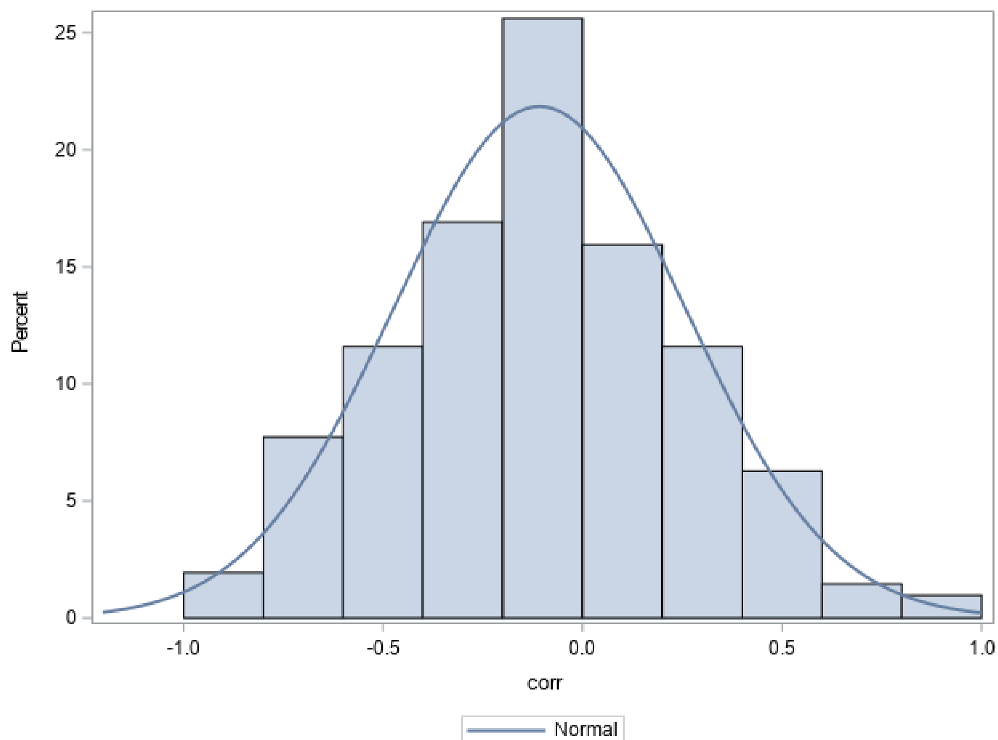


Figure 3: **Distribution of Fund Flows Pooled Across Funds Over Time.** This figure plots the distribution of fund flows pooled across funds and time between January 2005 and June 2020. For comparison, a normal distribution of best fit is overlaid, to show that the distribution of fund flows has excess kurtosis.

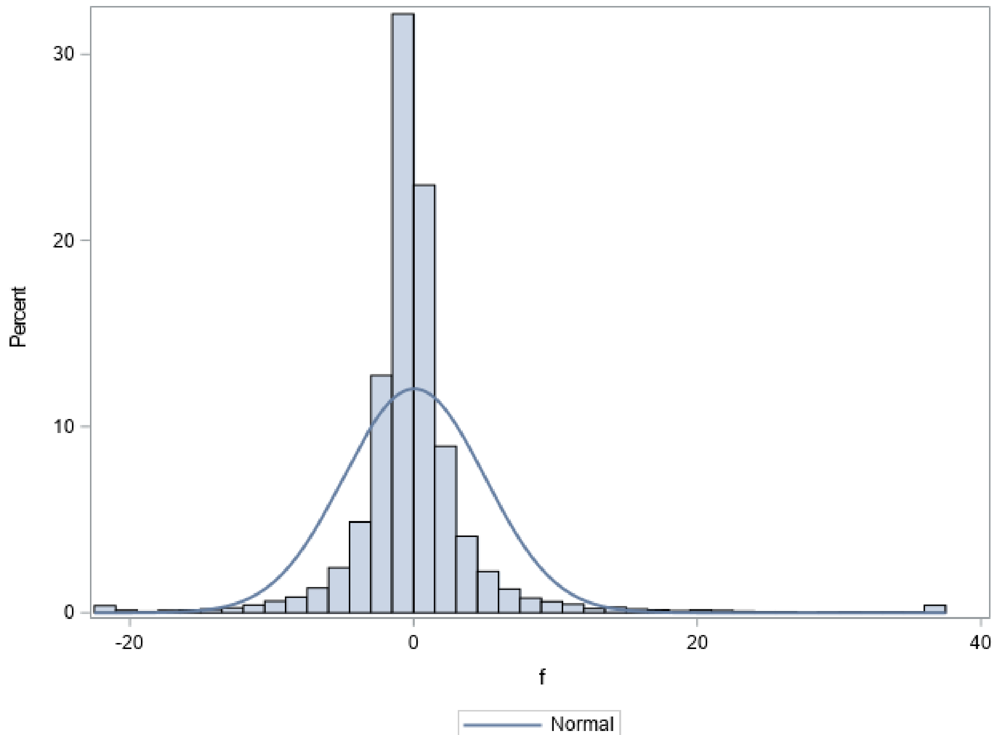


Figure 4: **Expected liquidation cost for no-derivative funds.** This figure plots the expected portfolio liquidation cost as a function of a fund's proportion of cash and the bond's liquidity cost, assuming that investor fund flows are normally distributed with the same mean and standard deviation as those for funds which never hold derivatives. The vertical lines mark the mean proportion of cash for a no-derivative fund, and a 95% confidence interval for cash.

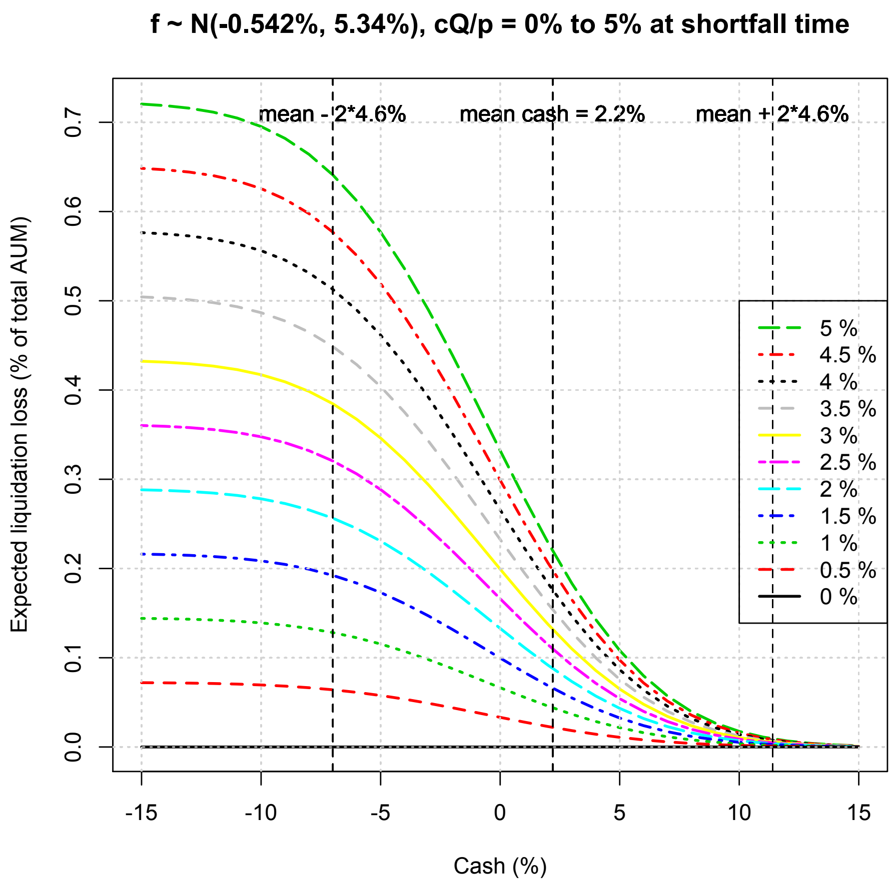
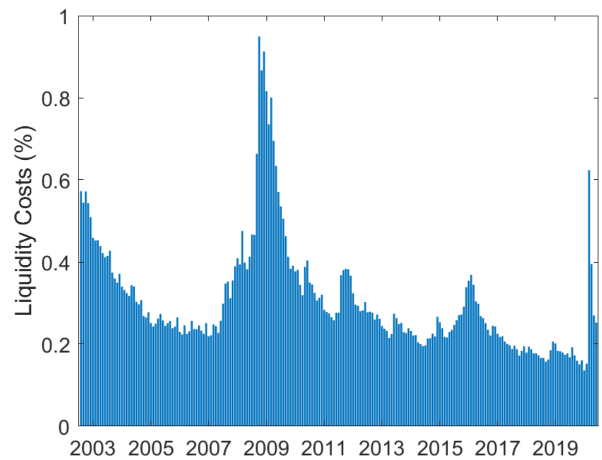
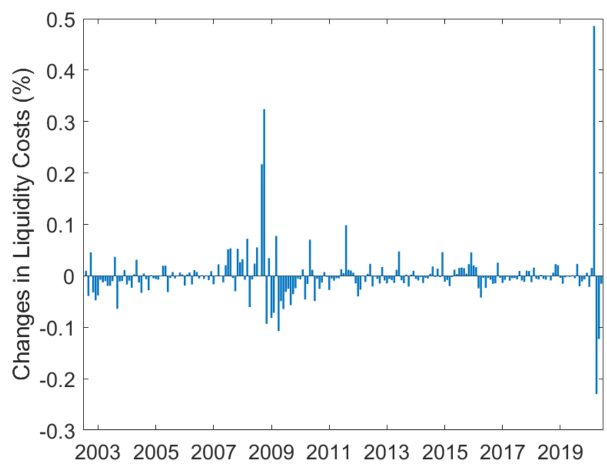


Figure 5: **Asset Prices Over Time.** This figure plots liquidity costs, the change in liquidity costs, and corporate bond returns in the top, middle and bottom panels, respectively. Liquidity costs are measured as half the difference between the mean prices at which customers buy from, and sell to, dealers in each month. Corporate bond returns are a weighted average of individual bond returns held by mutual funds in each month.

Panel A: Liquidity Costs



Panel B: Changes in Liquidity Costs



Panel C: Corporate Bond Returns

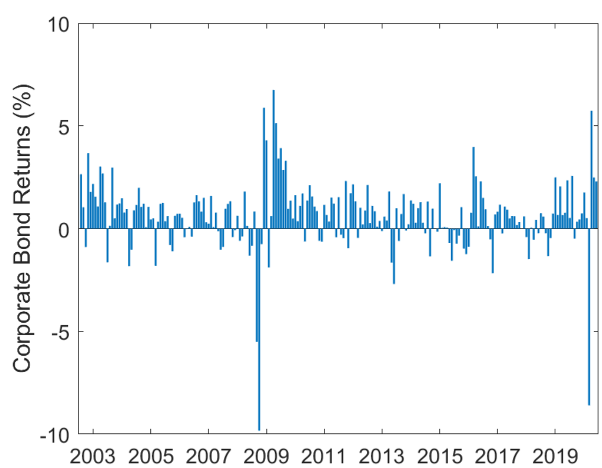


Figure 6: **Aggregate selling and bond price haircut at time $t+1$.** This figure plots funds' aggregate selling and the bond price's percentage haircut from its fundamental value at time $t+1$, in the top and bottom panels respectively, as a function of the bond's fundamental value (v_{t+1}), price sensitivity to selling (c_{t+1}), and funds' aggregate cash shortfall ($\sum_f (cash_t^f - flows_{t+1}^f)$). The default calibration is $v_{t+1} = \$100$, cash shortfall = \$100 million, $c_{t+1} = 5.6 \times 10^{-7}$, and each plot shows variation in one of these parameters.

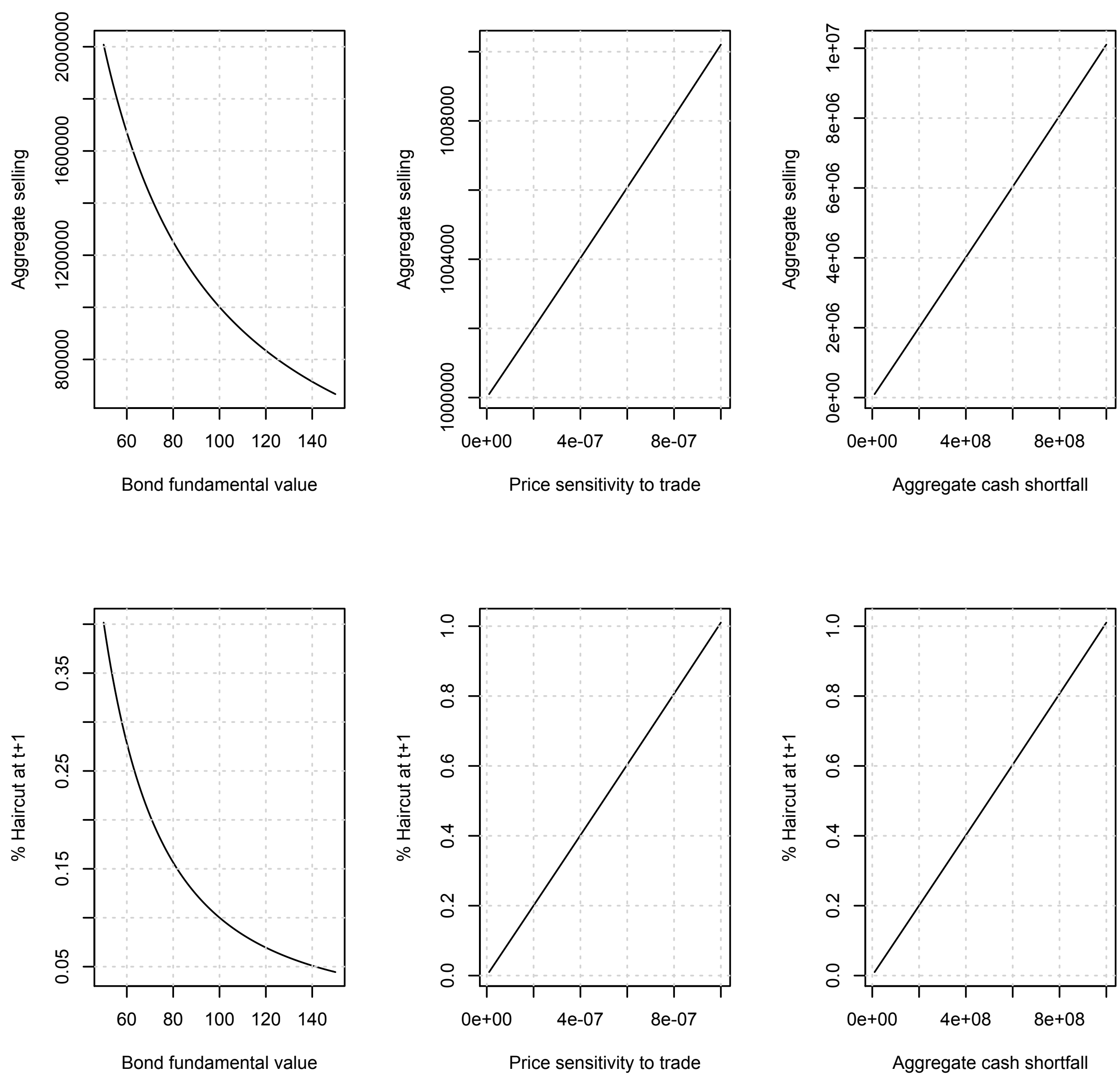


Figure 7: **The effect of aggregate expected future outflows, current aggregate cash holdings, and aggregate cash shortfall on bond trading, bond haircuts, and expected bond returns.** This figure plots a fund's bond buying at time t as a percentage of total net assets, the bond price's haircut as a percentage of its fundamental value, the bond's expected return from time t to $t+1$, and the time-t expected haircut as a percentage of fundamental value at time $t+1$ on the graphs on the left, second left, second right, and right sides, respectively. The top row of graphs shows the effect of varying funds' expected outflows at time $t+1$, and the bottom row shows the effect of varying funds' cash holdings entering time t. The dashed lines denote the limiting case where the expected haircut at time $t+1$ is zero.

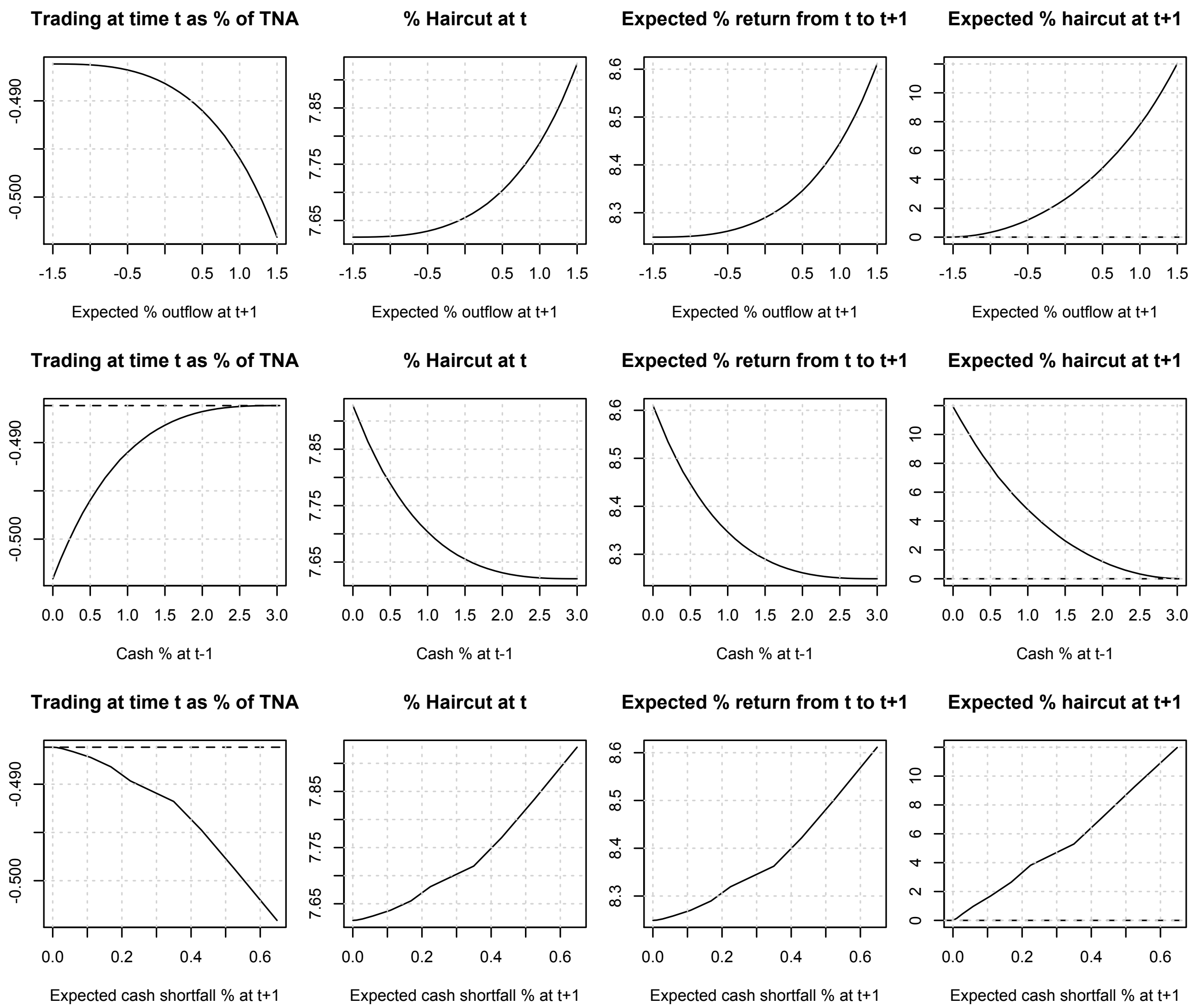


Figure 8: **The effect of aggregate cash holdings, risk aversion, and outflow uncertainty on bond trading, bond haircuts, and expected bond returns.** This figure plots aggregate funds' bond buying at time t as a percentage of total net assets, the bond price's haircut as a percentage of its fundamental value at time t, the bond's expected return from time t to $t+1$, the time-t expected haircut at time $t+1$ as a percentage of fundamental value, and an individual fund's bond trading on the graphs from left to right. The leftmost 4 columns are plotted as a function of aggregate cash holdings, and the right column is plotted as a function of the individual fund's cash holding. The top row of graphs shows the default calibration with risk penalty parameter $\lambda = 10^{-10}$, and uniform outflow distribution of [-3.49%, 3.55%]. The middle row shows the effect of increasing the risk penalty parameter to $\lambda = 10^{-9}$. The bottom row shows the effect of also reducing the outflow distribution to [-1%, 1%]. All graphs are plotted as a function of the funds' cash as a percentage of total net assets before they trade at time t.

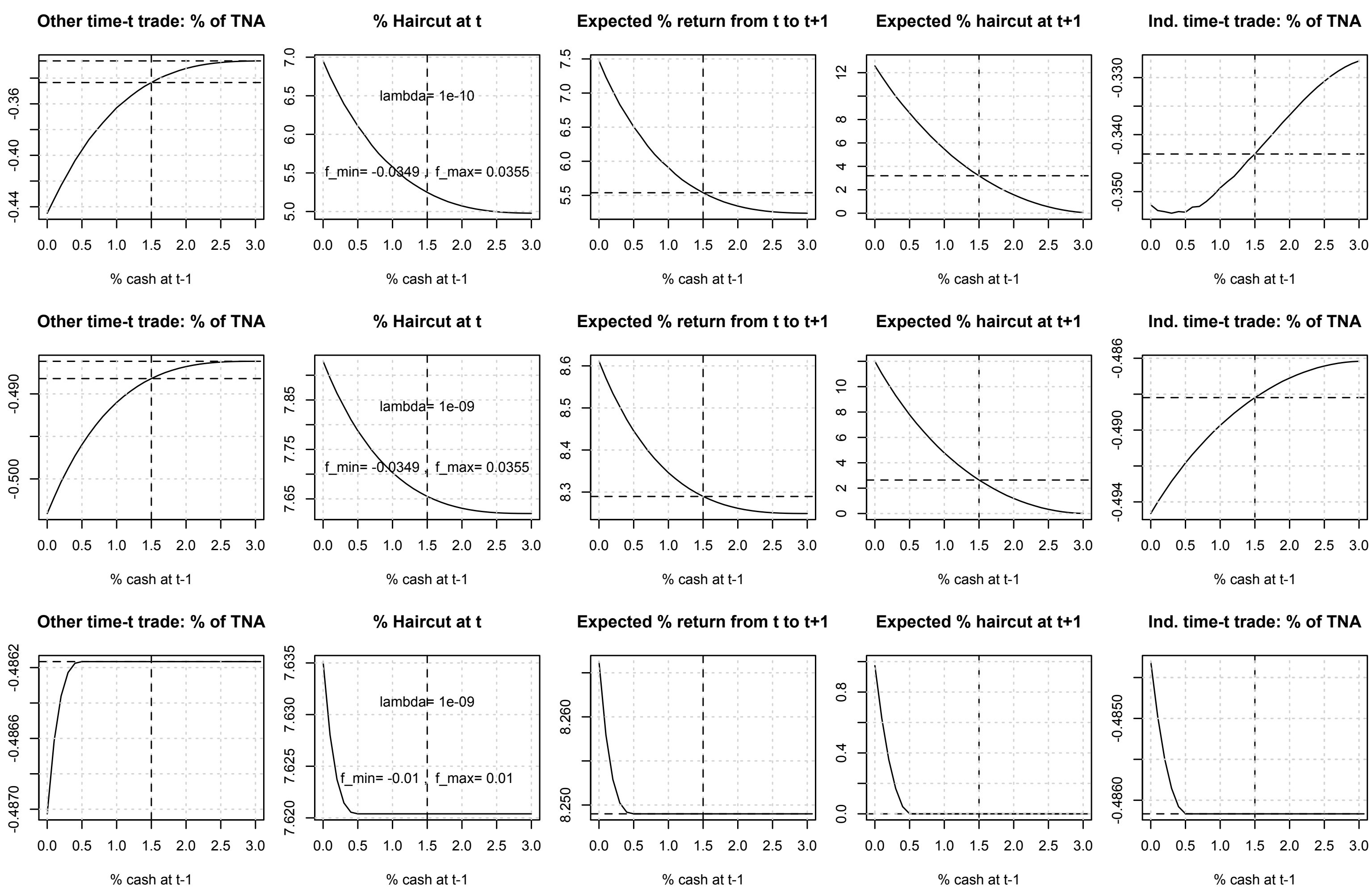


Table 1: **Summary Statistics.** This table shows summary statistics for key variables between July 2002 and June 2020. c denotes liquidity costs measured as the mean difference between prices when customers are buying and selling within a month, divided by two. Δc is the change in those liquidity costs. 1{IG} is an indicator variable, equal to 1 if the bond's credit rating is investment grade, and 0 if it's high yield. Duration is the bond's duration, as a measure of interest rate risk. Aggregate Mean Trade is the percentage increase in funds' bond holding (in number of shares) averaged across all funds. Aggregate Cash Shortfall is the cash reserves at the beginning of the month minus outflows during the month, over the lagged TNA, averaged across all funds (so a negative value means outflows being larger than the cash reserves). Outstanding denotes the amount of the bond issue still outstanding in US dollars. $Volume denotes the total monthly trading volume in millions of dollars. Fund Flows denote investor fund flows in percent. Fund Cash/TNA denotes the ratio of funds' cash to total net assets, in percent.

Variables	#Obs.	Mean	Std. Dev.	P10	P25	P50	P75	P90
c	977982	0.29	0.33	0.05	0.10	0.19	0.36	0.63
Δc	894802	0	0.29	-0.23	-0.08	0	0.08	0.23
Bond Returns	1034420	0.58	4.30	-1.88	-0.37	0.42	1.53	3.28
1{IG}	1027232	0.75	0.43	0	0	1	1	1
Duration	1064358	6.06	4.14	1.75	3.08	4.96	7.58	12.96
Aggregate Mean Trade	953849	0.31	7.25	-1.09	0	0	0	1.01
Aggregate Cash Shortfall	1291274	4.36	5.76	-0.45	1.31	3.37	6.14	10.49
Log(Outstanding)	1072073	13.09	0.79	12.21	12.61	13.12	13.53	14.12
Log($Volume)	1072716	16.57	1.98	13.94	15.54	16.86	17.9	18.74
Fund Flows	39065	0.01	5.25	-3.55	-1.52	-0.27	1.03	3.49
Fund Cash/TNA	32299	4.82	6.54	0.47	1.40	3.08	5.95	11.16

Table 2: **Summary Statistics - GFC.** This table shows summary statistics for key variables in the Global Financial Crisis of September 2008. c denotes liquidity costs measured as the mean difference between prices when customers are buying and selling within a month, divided by two. Δc is the change in those liquidity costs. 1{IG} is an indicator variable, equal to 1 if the bond's credit rating is investment grade, and 0 if it's high yield. Duration is the bond's duration, as a measure of interest rate risk. Aggregate Mean Trade is the percentage increase in funds' bond holding (in number of shares) averaged across all funds. Aggregate Cash Shortfall is the cash reserves at the beginning of the month minus outflows during the month, over the lagged TNA, averaged across all funds (so a negative value means outflows being larger than the cash reserves). Outstanding denotes the amount of the bond issue still outstanding in US dollars. $Volume denotes the total monthly trading volume in millions of dollars. Fund Flows denote investor fund flows in percent. Fund Cash/TNA denotes the ratio of funds' cash to total net assets.

Variables	#Obs.	Mean	Std. Dev.	P10	P25	P50	P75	P90
c	3362	0.66	0.62	0.09	0.21	0.46	0.89	1.55
Δc	2887	0.22	0.59	-0.33	-0.06	0.13	0.44	0.93
Bond Returns	3865	-5.51	8.30	-14.4	-7.44	-3.44	-0.79	0.91
1{IG}	3985	0.70	0.46	0	0	1	1	1
Duration	4080	5.20	3.14	1.77	2.92	4.43	6.63	10.64
Aggregate Mean Trade	3122	0.30	6.70	0	0	0	0	0
Aggregate Cash Shortfall	4255	5.55	7.37	-0.72	0.9	3.69	8.05	15.81
Log(Outstanding)	4094	12.96	0.79	12.07	12.43	12.9	13.46	13.96
Log($Volume)	4095	15.82	2.33	12.32	14.49	16.32	17.49	18.34
Fund Flows	203	-1.09	5.83	-4.26	-2.44	-1.12	-0.02	1.20
Fund Cash/TNA	181	6.98	8.04	0.62	2.01	4.26	10.28	16.19

Table 3: **Summary Statistics - Covid-19.** This table shows summary statistics for key variables at the start of the Covid outbreak in March 2020. c denotes liquidity costs measured as the mean difference between prices when customers are buying and selling within a month, divided by two. Δc is the change in those liquidity costs. 1{IG} is an indicator variable, equal to 1 if the bond's credit rating is investment grade, and 0 if it's high yield. Duration is the bond's duration, as a measure of interest rate risk. Aggregate Mean Trade is the percentage increase in funds' bond holding (in number of shares) averaged across all funds. Aggregate Cash Shortfall is the cash reserves at the beginning of the month minus outflows during the month, over the lagged TNA, averaged across all funds (so a negative value means outflows being larger than the cash reserves). Outstanding denotes the amount of the bond issue still outstanding in US dollars. $Volume denotes the total monthly trading volume in millions of dollars. Fund Flows denote investor fund flows in percent. Fund Cash/TNA denotes the ratio of funds' cash to total net assets.

Variables	#Obs.	Mean	Std. Dev.	P10	P25	P50	P75	P90
c	6617	0.62	0.52	0.12	0.27	0.49	0.82	1.29
Δc	6148	0.49	0.49	0.01	0.18	0.38	0.67	1.10
Bond Returns	6579	-8.60	11.08	-19.53	-10.77	-5.39	-2.03	-0.43
1{IG}	6127	0.85	0.36	0	1	1	1	1
Duration	6667	7.06	5.16	1.63	2.95	5.49	10.82	15.57
Aggregate Mean Trade	5885	0.07	7.89	-3.03	0	0	0	1.07
Aggregate Cash Shortfall	9435	-0.24	6.86	-5.76	-3.81	-1.27	0.92	7.13
Log(Outstanding)	6833	13.32	0.71	12.60	12.90	13.29	13.82	14.22
Log($Volume)	6834	16.99	1.98	14.36	15.95	17.22	18.30	19.20
Fund Flows	426	-3.12	7.26	-9.77	-6.13	-3.25	-1.01	1.56
Fund Cash/TNA	336	3.87	5.50	0.16	1.23	2.77	5.50	9.26

Table 4: **Risk Exposure to the Bond Market.** This table shows the bond market risk exposure (β) of mutual funds. Funds are categorised as Amplifying or Hedging if their derivative use amplifies or hedges their other portfolio returns, specifically the correlation of their derivative returns with their non-derivative returns between July 2019 and January 2020 is in the top or bottom tercile, or None if they never hold derivatives. Also shown is their bond market α. t-stats are in parentheses.

	Amplify	None	Hedge
Market β	0.744	0.804	0.742
	(15.69)	(38.59)	(14.47)
Market α	-0.007	0.017	0.039
	(-0.14)	(0.86)	(0.76)
R^2	0.0925	0.2198	0.1266
Observations	2418	5286	1446

Table 5: **Fund Returns, Flows, and Characteristics by Derivative Use.** This table shows the mean, median, and standard deviation of monthly mutual fund returns, investor fund flows, expense ratios, and total net assets. Funds are categorised as Amplifying or Hedging if their derivative use amplifies or hedges their other portfolio returns, specifically the correlation of their derivative returns with their non-derivative returns is in the top or bottom tercile, or None if they never hold derivatives. Fund returns, fund flows, and expense ratio are in percent. Total net assets are in millions of dollars.

	Mean			Median			Std. Dev.		
	Amplify	None	Hedge	Amplify	None	Hedge	Amplify	None	Hedge
Fund Returns	0.271	0.295	0.352	0.417	0.331	0.38	2.289	1.584	1.89
Fund Flows	-0.415	-0.086	0.647	-0.353	-0.241	0.097	4.355	4.999	4.778
Expense Ratio	0.731	0.684	0.633	0.704	0.64	0.61	0.308	0.296	0.281
Total Net Assets	2816	1194	4193	745	206	777	5422	4224	9419
Others	4.9	8.2	10.5	2.2	2.1	2.6	12.6	20.2	20.8

Table 6: **Holdings by Derivative Use - Quarterly.** This table shows mutual fund holdings, averaged quarterly within one of three fund groups: funds are categorised as Amplifying or Hedging if their derivative use amplifies or hedges their other portfolio returns, or None if they never hold derivatives. Cash-derivatives denotes cash specifically offset for funds' derivative holdings. Government denotes government bonds. Corporate denotes corporate bonds. Municipal denotes municipal bonds. Securitized denotes asset-backed and mortgage-backed securities.

	Mean			Median			Std. Dev.		
	Amplify	None.	Hedge	Amplify	None	Hedge	Amplify	None	Hedge
Cash	-0.5	1.2	-1.1	0	0	0	11.4	4.2	15.7
Cash-Derivatives	-0.2	0.3	-0.3	0	0	0	4.3	4.4	15.5
Government	18.8	22.7	32.5	4.2	14.1	29.5	24.5	24	32.6
Corporate	66.9	58.4	50.7	84.1	55.3	41.4	30.8	32.3	31.6
Derivatives	1.1	0	-0.8	0	0	0	9.1	0	16.5
Municipal	2.8	1.8	0.7	0	0	0	12	6.6	1.8
Securitized	6.1	6.4	10.3	1.3	0.4	6.5	8.9	11.6	11.5
Others	5.2	9.1	8.5	2.5	2.3	2.6	11.7	22	18.3

Table 7: **Trading of Corporate Bonds in Response to Flows and Cash Holdings.** This table shows the results of panel regressions of mutual funds' corporate bond tradings on several factors between July 2002 and June 2020. Bond trading is computed as the proportional changes in the number of bond shares, which controls for changes in prices. Flows is the fund's monthly net flows. Cash is the fund's cash holdings at the beginning of the month. Illiquidity is monthly bond illiquidity computed as the average of differences between the daily mean prices at which customers buy from, and sell to, dealers divided by two. Excess returns are monthly bond returns over the risk-free rate at the beginning of the month. Standard errors are clustered at fund level. t-statistics are in parentheses.

	Outflows Sample	Inflows Sample
Flows	0.527	0.468
	(8.98)	(4.80)
Flows*Cash	-0.013	-0.006
	(-4.01)	(-1.48)
Cash	0.013	0.041
	(0.83)	(2.35)
Flows*Illiquidity	-0.015	-0.098
	(-0.21)	(-1.85)
Illiquidity	0.153	-0.045
	(0.78)	(-0.25)
Flows*1{Investment Grade}	-0.098	0.046
	(-1.75)	(0.44)
1{Investment Grade}	-0.738	-1.05
	(-5.95)	(-4.97)
Flows*Duration	0.000	0.008
	(0.02)	(0.65)
Duration	-0.008	0.019
	(-0.58)	(0.78)
Flows*Excess returns	-0.007	0.002
	(-1.41)	(0.51)
Excess returns	-0.019	0.019
	(-1.11)	(1.11)
Year-Month Fixed Effects	Yes	Yes
R^2	0.0147	0.0365
Observations	1051458	930088

Table 8: **Trading of Corporate Bonds by Derivative Use.** This table shows the results of panel regressions of mutual funds' corporate bond trading on several factors between July 2002 and June 2020 by funds' derivative use. Funds are categorized as Amplifying or Hedging if the correlation of their derivative returns with their non-derivative returns is in the top or bottom tercile, or None if they never hold derivatives. Bond trading is computed as the proportional changes in the number of bond shares, which controls for changes in prices. Flows is the fund's monthly net flows. Cash is the fund's cash holdings at the beginning of the month. Illiquidity is monthly bond illiquidity computed as the average of differences between the daily mean prices at which customers buy from, and sell to, dealers divided by two. Excess returns are monthly bond returns over the risk-free rate at the beginning of the month. Standard errors are clustered at fund level. t-statistics are in parentheses.

	Outflows Sample		
	Amplify	None	Hedge
Flows	0.581	0.542	0.254
	(5.58)	(5.08)	(2.55)
Flows*Cash	-0.044	-0.01	-0.02
	(-2.62)	(-1.51)	(-8.68)
Cash	-0.053	0.061	-0.037
	(-0.49)	(1.58)	(-2.14)
Flows*Illiquidity	-0.03	-0.073	-0.066
	(-0.18)	(-1.37)	(-0.47)
Illiquidity	-0.057	-0.154	-0.142
	(-0.17)	(-0.91)	(-0.4)
Flows*1{Investment Grade}	-0.035	-0.087	0.178
	(-0.49)	(-1.17)	(2.02)
1{Investment Grade}	-0.422	-0.61	-0.684
	(-1.1)	(-3.76)	(-1.41)
Flows*Duration	-0.003	-0.004	0.017
	(-0.22)	(-0.66)	(2.01)
Duration	0.069	0.01	0.01
	(1.99)	(0.54)	(0.31)
Flows*Excess returns	0.01	-0.017	0.022
	(1.29)	(-2.51)	(2.23)
Excess returns	0.044	-0.036	0.057
	(1.69)	(-1.4)	(1.13)
Year-Month Fixed Effects	Yes	Yes	Yes
R^2	0.01225	0.02042	0.02559
Observations	120202	407130	75754

Table 9: **Trading of Government Bonds in Response to Flows and Cash Holdings.** This table shows the results of panel regressions of mutual funds' government bond tradings on a number of factors between July 2002 and June 2020. Bond trading is computed as the proportional changes in the number of bond shares, which controls for changes in prices. Flows is the fund's monthly net flows. Cash is the fund's cash holdings at the beginning of the month. Illiquidity is monthly bond illiquidity computed as the average of differences between the daily mean prices at which customers buy from, and sell to, dealers divided by two. Returns are monthly bond returns. Standard errors are clustered at fund level. t-statistics are in parentheses.

	Outflows Sample	Inflows Sample
Flows	0.65258	0.62014
	(3.81)	(3.26)
Flows*Cash	-0.0067	-0.00323
	(-0.56)	(-0.46)
Cash	0.0216	-0.00152
	(0.69)	(-0.04)
Flows*Illiquidity	-0.00414	1.49914
	(0.00)	(0.47)
Illiquidity	-7.18254	-11.9602
	(-0.75)	(-1.05)
Flows*Duration	-0.00003	0.00000
	(-1.24)	(0.12)
Duration	0.00025	0.0004
	(2.94)	(3.93)
Flows*Returns	0.02439	0.01769
	(1.28)	(0.96)
Returns	0.22396	-0.08758
	(2.50)	(-0.94)
Year-Month Fixed Effects	Yes	Yes
R^2	0.011	0.026
Observations	70553	60960

Table 10: **Trading Sensitivities by Magnitude of Outflows Relative to Cash Holdings - Outflows Sample.** This table shows the results of a regression of mutual funds' corporate bond and cash trading on the interaction of investor outflows and funds' cash reserves, grouped into outflows being less than 50%, 50-100%, 100-150%, and more than 150% of cash reserves. Standard errors are clustered at the monthly level. t-stats are in parentheses.

	Sensitivity of cash trading	Sensitivity of bond trading
Flows*1{|Outflows| $<$ 0.5Cash}	2.697	0.181
	(17.82)	(1.79)
Flows*1{0.5Cash$\leq$ |Outflows| $<$Cash}	0.734	0.239
	(10.6)	(4.61)
Flows*1{Cash$\leq$ |Outflows| $<$1.5Cash}	0.412	0.251
	(7.91)	(5.57)
Flows*1{1.5Cash$\leq$ |Outflows|}	-0.008	0.492
	(-0.31)	(8.84)
Year-Month Fixed Effects	Yes	Yes
Controls	No	Yes
R^2	0.560	0.015
Observations	11007	1051458

Table 11: **Liquidity Costs of Corporate Bonds.** This table shows the results of a regression of the liquidity costs of corporate bonds on several factors. Aggregate Mean Trade is the percentage increase in funds' bond holding (in number of shares) averaged across all funds. Aggregate Cash Shortfall is the cash reserves at the beginning of the month minus outflows during the month, over the lagged TNA, averaged across all funds (so a negative value means outflows being larger than the cash reserves). Outstanding denotes the amount of the bond issue still outstanding in US dollars. $Volume denotes the total monthly trading volume in millions of dollars. Fund Flows denote investor fund flows in percent. Duration is the bond's duration, as a measure of interest rate risk. 1{IG} is an indicator variable, equal to 1 if the bond's credit rating is investment grade, and 0 if it's high yield. Standard errors are clustered at the monthly level. t-stats are in parentheses.

	All Sample	GFC Sample	Covid-19 Sample
Aggregate Mean Trade	-0.0002	-0.0039	-0.0018
	(-3.29)	(-2.71)	(-2.02)
Aggregate Cash Shortfall	0.0000	0.0013	0.0032
	(0.01)	(0.81)	(3.19)
Log(Outstanding)	-0.0232	0.1649	-0.0957
	(-6.97)	(7.26)	(-5.33)
Log($volume) lagged	0.0021	-0.0084	0.0273
	(3.07)	(-0.87)	(3.42)
Log($volume)	-0.0199	-0.0154	0.0048
	(-16.95)	(-1.56)	(0.52)
Duration lagged	0.0164	0.0287	0.0253
	(41.52)	(6.37)	(17.27)
1{Investment Grade}	-0.0635	0.1691	-0.1904
	(-15.97)	(6.40)	(-7.16)
Year-Month Fixed Effects	Yes	No	No
R^2	0.589	0.597	0.639
Observations	705638	2259	4629

Table 12: **Changes in Liquidity Costs of Corporate Bonds.** This table shows the results of a regression of changes in the liquidity costs of corporate bonds on several factors. Aggregate Mean Trade is the percentage increase in funds' bond holding (in number of shares) averaged across all funds. Aggregate Cash Shortfall is the cash reserves at the beginning of the month minus outflows during the month, over the lagged TNA, averaged across all funds (so a negative value means outflows being larger than the cash reserves). Outstanding denotes the amount of the bond issue still outstanding in US dollars. $Volume denotes the total monthly trading volume in millions of dollars. Fund Flows denote investor fund flows in percent. Duration is the bond's duration, as a measure of interest rate risk. 1{IG} is an indicator variable, equal to 1 if the bond's credit rating is investment grade, and 0 if it's high yield. Standard errors are clustered at the monthly level. t-stats are in parentheses.

	All Sample	GFC Sample	Covid-19 Sample
Aggregate Mean Trade	-0.0001	-0.0027	-0.0019
	(-2.93)	(-1.45)	(-2.36)
Aggregate Cash Shortfall	-0.0001	0.0007	0.0025
	(-0.94)	(0.45)	(2.52)
Log(Outstanding)	0.0000	0.0943	-0.0634
	(0.04)	(4.25)	(-3.60)
Log($volume) lagged	0.0193	0.0214	0.0203
	(23.26)	(1.86)	(2.57)
Log($volume)	-0.0189	-0.0058	0.0175
	(-20.7)	(-0.50)	(1.94)
Duration lagged	0.0003	0.0038	0.0155
	(1.26)	(0.80)	(10.49)
1{Investment Grade}	-0.0009	0.172	-0.0732
	(-0.46)	(6.53)	(-3.01)
Year-Month Fixed Effects	Yes	No	No
R^2	0.050	0.520	0.532
Observations	671708	2043	4488

Table 13: **Corporate Bond Returns.** This table shows the results of a regression of corporate bond returns on several factors. Aggregate Mean Trade is the percentage increase in funds' bond holding (in number of shares) averaged across all funds. Aggregate Cash Shortfall is the cash reserves at the beginning of the month minus outflows during the month, over the lagged TNA, averaged across all funds (so a negative value means outflows being larger than the cash reserves). Outstanding denotes the amount of the bond issue still outstanding in US dollars. $Volume denotes the total monthly trading volume in millions of dollars. Fund Flows denote investor fund flows in percent. Duration is the bond's duration, as a measure of interest rate risk. 1{IG} is an indicator variable, equal to 1 if the bond's credit rating is investment grade, and 0 if it's high yield. Standard errors are clustered at the monthly level. t-stats are in parentheses.

	All Sample	GFC Sample	Covid-19 Sample
Aggregate Mean Trade	0.0073	0.0221	0.0424
	(5.43)	(0.98)	(1.79)
Aggregate Cash Shortfall	-0.0051	-0.0321	-0.0782
	(-1.42)	(-1.75)	(-4.29)
Log(Outstanding)	-0.054	-1.8525	2.8868
	(-1.55)	(-5.63)	(7.81)
Log($volume) lagged	-0.0652	0.327	-0.9006
	(-4.31)	(3.13)	(-6.66)
Log($volume)	0.0797	-0.7461	0.5238
	(5.33)	(-6.33)	(3.00)
Duration lagged	0.031	-0.2993	-0.3997
	(2.15)	(-6.62)	(-16.86)
1{Investment Grade}	-0.1713	1.3126	12.1466
	(-1.20)	(3.26)	(15.95)
Year-Month Fixed Effects	Yes	No	No
R^2	0.191	0.405	0.504
Observations	757705	2616	4756

6 Appendix

Some extra detail is provided for the proofs in the theoretical model.

6.1 Proofs

We can re-write the fund's utility function by conditioning on its investor flows at time $t+1$:

$$
\begin{aligned}
E_t\left[cash_{t+1} + bonds_{t+1}v_{t+1}\right] &= E_t\left[E_t\left[cash_{t+1} + bonds_{t+1}v_{t+1} \mid f_{t+1}\right]\right] \\
&= \int_{cash_t}^{\bar{f}} g(f)E_t\left[\left(bonds_{t-1} + q_t - \frac{f - cash_t}{p_{t+1}}\right)v_{t+1}\right]df \\
&\quad + \int_{\underline{f}}^{cash_t} g(f)E_t\left[cash_t - f + \left(bonds_{t-1} + q_t\right)v_{t+1}\right]df \\
&= \int_{\underline{f}}^{cash_t} g(f)E_t\left[cash_t - f\right]df \\
&\quad + \left(bonds_{t-1} + q_t\right)E_t[v_{t+1}]\int_{\underline{f}}^{\bar{f}} g(f)df \\
&\quad - \int_{cash_t}^{\bar{f}} g(f)E_t\left[\left(\frac{f - cash_t}{p_{t+1}}\right)v_{t+1}\right]df \\
&= \int_{\underline{f}}^{cash_t} g(f)E_t\left[cash_t - f\right]df + \int_{cash_t}^{\bar{f}} g(f)E_t\left[cash_t - f\right]df \\
&\quad + \left(bonds_{t-1} + q_t\right)E_t[v_{t+1}] \\
&\quad - \int_{cash_t}^{\bar{f}} g(f)E_t\left[\left(\frac{cash_t - f}{p_{t+1}}\right)p_{t+1}\right]df - \int_{cash_t}^{\bar{f}} g(f)E_t\left[\left(\frac{f - cash_t}{p_{t+1}}\right)v_{t+1}\right]df \\
&= \int_{\underline{f}}^{\bar{f}} g(f)E_t\left[cash_t - f\right]df + \left(bonds_{t-1} + q_t\right)E_t[v_{t+1}] \\
&\quad - \int_{cash_t}^{\bar{f}} g(f)E_t\left[\left(\frac{cash_t - f}{p_{t+1}}\right)\left(p_{t+1} - v_{t+1}\right)\right]df
\end{aligned}
$$

The utility function becomes:

$$\begin{aligned}
E_t\left[cash_{t+1} + bonds_{t+1}v_{t+1}\right] - \lambda_t(p_t bonds_t)^2 \quad = \quad & \underbrace{cash_t - E_t[f_{t+1}] + (bonds_{t-1} + q_t)\, E_t[v_{t+1}]}_{\text{AUM if no cash shortfall}} \\
& - \underbrace{E_t\left[(p_{t+1} - v_{t+1})\, q^-_{t+1} \mid cash_t < f_{t+1}\right]}_{\text{AUM deduction if shortfall}} \\
& - \underbrace{\lambda_t(p_t(bonds_{t-1} + q_t))^2}_{\text{penalty for risk}}
\end{aligned}$$

Substituting in $cash_t = cash_{t-1} - f_t - p_t q_t$:

$$\begin{aligned}
& \int_{cash_t}^{\bar{f}} g(f) E_t\left[\left(\frac{cash_t - f}{p_{t+1}}\right)(p_{t+1} - v_{t+1})\right] df \\
= \quad & \frac{1}{\bar{f} - \underline{f}} \int_{cash_{t-1} - f_t - p_t q_t}^{\bar{f}} E_t\left[\left(\frac{cash_{t-1} - f_t - p_t q_t - f}{p_{t+1}}\right)(p_{t+1} - v_{t+1})\right] df \\
= \quad & \frac{1}{\bar{f} - \underline{f}} E_t\left[\left(\frac{(cash_{t-1} - f_t - p_t q_t) f - f^2/2}{p_{t+1}}\right)(p_{t+1} - v_{t+1})\right]_{cash_{t-1} - f_t - p_t q_t}^{\bar{f}} \\
= \quad & \frac{1}{\bar{f} - \underline{f}} E_t\left[\left(\frac{(cash_{t-1} - f_t - p_t q_t)\bar{f} - \bar{f}^2/2}{p_{t+1}}\right)(p_{t+1} - v_{t+1})\right] \\
& - \frac{1}{\bar{f} - \underline{f}} E_t\left[\left(\frac{(cash_{t-1} - f_t - p_t q_t)^2/2}{p_{t+1}}\right)(p_{t+1} - v_{t+1})\right]
\end{aligned}$$

Using $p_{t+1} - v_{t+1} = c_{t+1}Q_{t+1}$, the first order condition with respect to q_t is:

$$\begin{aligned}
0 \quad = \quad & E_t[v_{t+1}] - p_t - 2\lambda_t p_t^2 (bonds_{t-1} + q_t) \\
& - \frac{p_t}{\bar{f} - \underline{f}} E_t\left[\left(cash_{t-1} - f_t - p_t q_t - \bar{f}\right)\left(\frac{c_{t+1}Q_{t+1}}{p_{t+1}}\right)\right]
\end{aligned}$$

Rearranging, and dividing by p_t:

$$p_t q_t \quad = \quad \frac{\overbrace{E_t[v_{t+1}/p_t] - 1}^{\text{expected return}} - \overbrace{2\lambda_t p_t bonds_{t-1}}^{\text{extra risk}} - \overbrace{\frac{1}{\bar{f} - \underline{f}}\left(cash_{t-1} - f_t - \bar{f}\right)}^{\text{expected \$ shortfall at time } t+1} \overbrace{E_t\left[\frac{c_{t+1}Q_{t+1}}{p_{t+1}}\right]}^{\text{\% illiquidity}}}{2\lambda_t - \frac{1}{\bar{f} - \underline{f}} E_t\left[\frac{c_{t+1}Q_{t+1}}{p_{t+1}}\right]}$$

Table A1: **Holdings by Derivative Use - Monthly.** This table shows mutual fund holdings, averaged monthly within one of three fund groups: funds are categorised as Amplifying or Hedging if their derivative use amplifies or hedges their other portfolio returns, or None if they never hold derivatives. Cash-derivatives denotes cash specifically offset for funds' derivative holdings. Government denotes government bonds. Corporate denotes corporate bonds. Municipal denotes municipal bonds. Securitized denotes asset-backed and mortgage-backed securities.

	Mean			Median			Std. Dev.		
	Amplify	None	Hedge	Amplify	None	Hedge	Amplify	None	Hedge
Cash	0	1.2	0.1	0	0	0	10.4	3.7	12.7
Cash-Derivatives	-0.2	0.3	0.1	0	0	0	3.9	4.2	10
Government	20.4	23.8	26.2	5	17.9	14.8	25.6	24	29.1
Corporate	63.9	57.2	54.9	81	51.5	46.6	32.2	31.8	31.3
Derivatives	0.9	0	-0.6	0	0	0	7.8	0	10.9
Municipal	3.3	1.9	0.6	0	0	0	13.4	7.3	1.6
Securitized	6.9	7.4	8.9	1.6	0.9	4	9.6	12.6	10.7
Others	4.9	8.2	10.5	2.2	2.1	2.6	12.6	20.2	20.8